POLISH JOURNAL OF SCIENCE
№95 (2026)

ISSN 3353-2389

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CONTENT

AGRICULTURAL SCIENCES

Jalilova L., Mehdiyeva N., Ahmadova A.
MODERN AMELIORATIVE STATE OF SOILS IN THE KURDAMIR REGION.....3

ECONOMIC SCIENCES

Ahmadzada M.
ENERGY PRICE SHOCKS AND THE FINANCIAL PERFORMANCE OF POLISH MANUFACTURING SMES: A SURVIVAL ANALYSIS (2023–2025).....6
Ahmadzada M.
THE WAGE-PRODUCTIVITY GAP IN THE POLISH SERVICE SECTOR: ARE RISING SALARIES OUTPACING ECONOMIC OUTPUT 12
Otargaliyev N.
RECOMMENDATIONS FOR RESTRUCTURING OF CURRENT FINANCIAL SYSTEM IN HEALTHCARE OF KAZAKHSTAN.....17
Sharofiddinov N.
IMPROVING THE PERSONNEL TRAINING SYSTEM IN THE CONTEXT OF THE DIGITAL TRANSFORMATION OF THE AGRO-INDUSTRIAL COMPLEX OF UZBEKISTAN ..19
Shoyev A.
IMPROVING THE SOCIAL MARKETING SYSTEM TO INCREASE THE EMPLOYMENT OF GRADUATES WITH DISABILITIES 22

MEDICAL SCIENCES

Aliyev R.
DISORDERS OF PSYCHOLOGICAL BEHAVIOR IN STUDENTS AND PSYCHOLOGICAL AND MEDICAL BIOLOGICAL METHODS OF ITS CORRECTION 24

PEDAGOGICAL SCIENCES

Aliyev S., Allahverdiyeva N., Yuzbashiyeva N.
METHODOLOGY FOR SOLVING STEREOMETRIC PROBLEMS: A SYSTEMATIC APPROACH TO SPATIAL THINKING 27

PHILOLOGICAL SCIENCES

Hovakimyan E., Hovhannisyan A.
THE CRUCIAL ROLE OF MENTAL MAPPING FOR REINFORCING COGNITIVE AND METACOGNITIVE PROCESSES ON READING COMPREHENSION 31
Kim S.
STRUCTURAL AND SEMANTIC TYPES OF COMPLEX MONO-MEMBER AND POLY-MEMBER SENTENCES WITH THE COMPONENT "WHAT" IN THE WORKS OF M. YU. LERMONTOV.....38

POLITICAL SCIENCES

Szilagyi L., Szenes Z.
POST-NEW START STRATEGIC STABILITY: PREDICTABILITY, TRANSPARENCY, AND RESTRAINT.....41

PSYCHOLOGICAL SCIENCES

Podborschi A.
INTERGENERATIONAL DIFFERENCES IN VALUE ORIENTATIONS IN CONDITIONS OF SOCIAL TRANSFORMATION: AN EMPIRICAL STUDY 52

TECHNICAL SCIENCES

Berezhnoy A.
APPROACHES TO BUILDING FAULT-TOLERANT DATA TRANSMISSION CHANNELS IN HIGH-LOAD SYSTEMS57
Gaudance Stanslaus Tesha
AUTOMATED DETECTION OF SWAHILI SCAM MESSAGES IN TANZANIA USING NATURAL LANGUAGE PROCESSING AND MACHINE LEARNING MODELS.....62
Avrunin G., Nikitin S., Moroz I., Tsenta Y.
ANALYSIS OF THE POSSIBILITIES OF CREATING GEARLESS MOBILE DRILLING AUG HYDRAULIC DRIVES 66

AGRICULTURAL SCIENCES

MODERN AMELIORATIVE STATE OF SOILS IN THE KURDAMIR REGION

Jalilova L.
https://orcid.org/0000-0003-0779-3501
Doctor of Philosophy (PhD) in Agrarian Sciences, Azerbaijan Republic Ministry of Science and Education Institute of Geography Public Legal Person
Mehdiyeva N.
https://orcid.org/0009-0008-0271-4118
PhD Student, Azerbaijan Republic Ministry of Science and Education Institute of Geography Public Legal Person
Ahmadova A.
https://orcid.org/0009-0008-4352-8346
PhD Student, Azerbaijan Republic Ministry of Science and Education Institute of Geography Public Legal Person
DOI: 10.5281/zenodo.18738381

Abstract
Rapid growth of population, increase of the agricultural plants due to the need for food products and improvement of the ameliorative state of soils under cultivation are an important problem of the day. From this point of view, the information about the soils in the experimental area selected in the Kurdamir region of the Shirvan plain was given in the presented article. The soils have heavy granulometric composition and meadow-grey type. According to the analysis results, the salt quantity of the undergrain soils was 0.10-0.59 % and this indicates that the experimental soils were non- salinized, they were salinized weakly and moderately. Generally, the irrigation norms should be followed correctly in order to protect ameliorative state and fertility of the soils.
Keywords: irrigated, ecological, fertility, salinization, salinity degree.

INTRODUCTION

Presence of the favourable climate, soil, hydrogeological condition is important in order to use soil efficiently in agricultural production. Increase of the soil fertility, higher, stable agricultural production, regulation of the water, heat and food regimes is possible due to soil amelioration measures. The soil fertility mostly depends on water and air regimes. In order to provide plants with fertility factors without interruption, the soil should have the amount of moisture required by the plants [2]. The ameliorative state of soils are also formed under the influence of the natural factors and irrigation economic system. The soil cover, climate situation, geological and geomorphological structure, irrigation water, hydrological and hydrogeological standard of the zone belong to the natural factors forming ameliorative state in the soil. The main indications which characterize ameliorative state of soils are considered salinization and solonetzification degrees, salinity type, sort, state of the soil solution, depth of the groundwater location, mineralization degree, irrigated water quality, earth relief, natural and artificial draining level[1]. Metternicht G.İ. and other researches show that the soil salinization creates serious ecological risk as a result of the natural or technogen processes at present [7].

The Kur-Araz lowland possessing a good condition for growing of the main agricultural plants and study of the ameliorative state of these soils in the country are an important problem. The Shirvan plain is situated in the Kur-Araz lowland and the researches were performed in the Kurdamir district [3].

RESEARCH OBJECT AND METHOD

The experimental area was selected as a research object in the undergrain soils and the soil samples were taken from the characteristic places (the coordinates were noted) in the Sorsor village of the Kurdamir region. The chemical analyses in the taken soil samples were fulfilled according to the wide-spread method in the republic [3].

ANALYSIS AND DISCUSSION

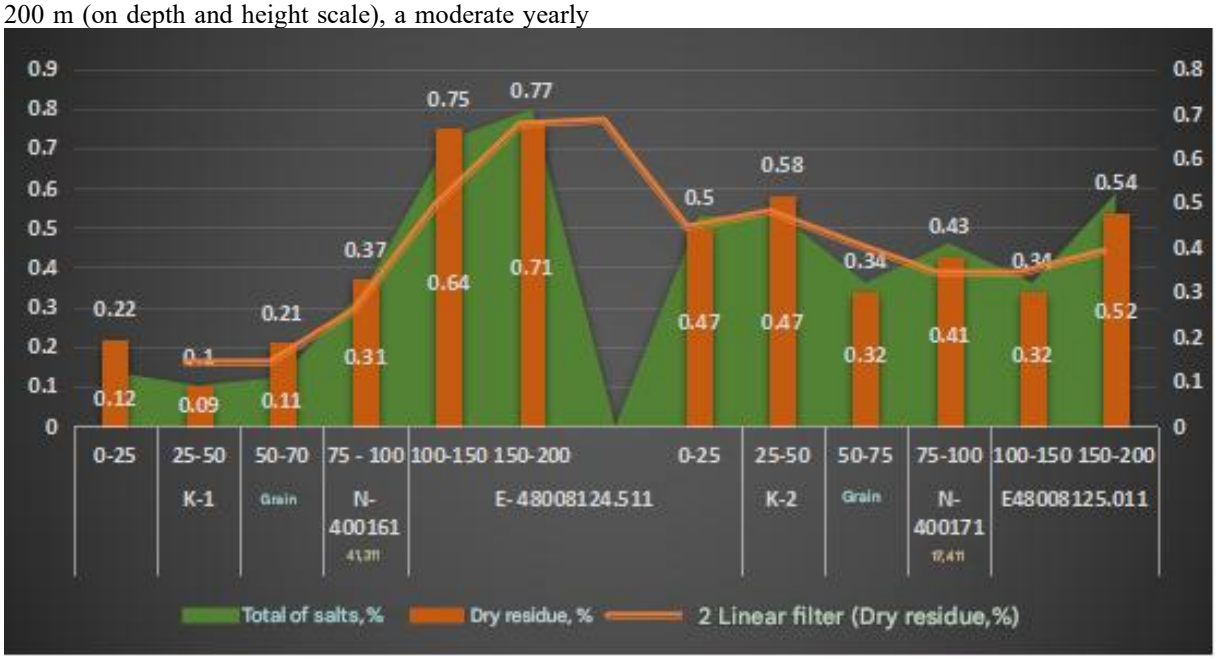
At present the soil reform in the republic aims to radically increase the efficiency of agro-industrial production and improve the population's food supply. Rationality of the irrigation and amelioration systems is of special importance because of the agricultural production in the irrigated soils. The international experiment indicates that the priorities for achieving efficiency in irrigated agriculture depend on economical development standard, physical state of the irrigation and amelioration systems, including exploitation organisation and other factors. The population growth and aggrivation of the ecological environment, including the observed global climatic changes require improvement of population with the qualitative food products in conditions of decrease of the fruitful soil funds and drinkable water resources, increase and intensification of the agricultural production. The basis of the irrigation agriculture is grain-growing, fodder-growing and cotton-growing in the country.

The agricultural production is obtained due to irrigations and the Kur-Araz lowland is a basic irrigated zone of the country. The soil-cover of the lowland is formed under the influence of the local factors and sufficiently colorful. As is known there are different salts in the soil and they differ for their toxicity. The classification of salts for their saltness rate and type was given by some scientists. V.R.Volobuyev divided lowland soils into types according to their salinization: sodium, chloride-sodium, chloride-calcium-magnesium,

sulphate-calcium, carbonate-calcium [9]. Recently, G.Z.Azizov divided the soils into salinity types: sodium, chloric, sulphate-chloric, chloric-sulfate and sulfate. After G.Z.Azizov, L.Z.Jalilova specified classification of the sulfatic salinized soils for saltness rate and type in the Shirvan plain and showed chloric-sulfatic-natrium, sulfatic-natrium (gypsum 1-2%), sulfatic (gypsum >2.0%) [4,5].

At present the most worrying issue is global climate change by the world countries and some international organisations and global research centers. The global climate changes affect different countries, including Azerbaijan. Desertification and soil degradation increased because of increase of temperature, floods, decrease of the river waters[6].

The researches were performed in the Kurdamir region located in the Shirvan plain. The Kurdamir belongs to the lowland economic region. A zone of the region is 163151 hectare and its main activity is plant-growing and cattle-breeding. A relief of the Kurdamir region is a plain and most of the area is below sea level. The climate –summer is drought mild hot semi-desert and dry steppe type. Here, the river network is sparse. The low flows of the Girdiman and Agsu rivers are in Kurdamir. The slope of the region is 1 degree, The calculations indicate that the altitude above sea level is 0-200 m (on depth and height scale), a moderate yearly temperature is 15^0 C, a yearly quantity of rains is 250-300 mm, the wind velocity 2-3 m/sec, dry subtropical climate [8]. Vegetation of the zone is different. Mainly, grey-meadow, grey and meadowe-grey soils spread. The calculations indicate that the moderate, strong salinized and saline soil areas constitute approximately 7.2 % of the non-salinized and weak saline soils. The soils are heavy by granulometric composition and they are calcareous along the whole profile. An absorption capacity of the same soils is high. The soils of the research area belong to meadow-grey soil type and the salt quantity was defined to study amelioratve state of soils in them. Accordin to the results, the salt number in the undergrain soils was 0.10-0.58%. CO_2 ion wasn't in anion composition of salts. HCO_2 ion was 0.012-0.058%, Cl ion was 0.014-0.171%. SO_4ion was 0.012-0.384%, Ca -0.020-0.057%, Mg-0.003-0.017% and Na+K was 0.002-0.125% in the salt cation composition. The consequences were shown in a graphic form. As we know, different types of salts exist in soil. Therefore, it was determined which type the salts belong to. The consequences indicate that the salts belong to sulphatic, chlorine-sulfatic type. The salt quantity in the experimental soils was shown in the following graphic. Productivity of the grain plant was 29-30 s/h in the experimental soils.



Graphic. Change graphic of salts in the experimental soils

Generally, the ecological changes happened in recent times affected ameliorative state of soils and the degradation processes in them accelerated as a result of these changes. For this purpose, it is important to conduct extensive researches for protection of the ameliorative state and fertility in soils. But the last investigations indicate that hydrogeological-ameliorative state of the irrigated soils improved noticeably and this is the result of the implementation of purposeful reclamation measures [10,11].

CONCLUSION

1. During the researches it was determined that the salt number of the undergrain soils was 0.10-0.59 % in the experimental areas. The same soils are sulfatic and chlorine-sulfaticfor the salt type.

2. It was determined that the soils in the experimental areas were non-salinized, weak and moderate salinized according to the obtained consequences. The productivity was 28-30 s/h in grain plant.

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ECONOMIC SCIENCES

ENERGY PRICE SHOCKS AND THE FINANCIAL PERFORMANCE OF POLISH MANUFACTURING SMES: A SURVIVAL ANALYSIS (2023–2025)

Ahmadzada M.
PhD candidate of Vistula University
DOI: 10.5281/zenodo.18738403

Abstract

Energy price volatility has become a core stress test for manufacturing small and medium-sized enterprises (SMEs) across Europe. This article examines whether energy price shocks translated into a higher risk of market exit among Polish manufacturing SMEs during 2023–2025, and how this risk interacted with balance-sheet resilience and export orientation. The study is designed as a survival analysis, where the outcome is time-to-exit over a 36-month window, and covariates capture energy-cost exposure alongside firm-level controls (leverage, liquidity, size, profitability, and exports) plus sector fixed effects. The empirical strategy uses Kaplan–Meier comparisons and a Cox proportional hazards specification, allowing the baseline hazard to remain unspecified. Results indicate that greater energy-shock exposure is associated with a meaningfully higher exit hazard, while liquidity and firm size reduce hazard and export orientation provides an additional buffer. These findings support a forward-looking view: policies that accelerate energy efficiency adoption and stabilize input-cost risk for SMEs can strengthen survival odds without relying on permanent price controls.

Keywords: energy price shocks; SMEs; manufacturing; survival analysis; Poland.

1. Introduction

Energy prices in Europe remained strategically important after 2022, and Poland's manufacturing SMEs entered 2023–2025 in an environment where energy costs and policy responses were still changing. Even when wholesale prices softened, many industrial users faced contract renewals, tariff changes, and uncertainty about future policy interventions. For SMEs, energy is a direct variable cost, but it also influences financing conditions: when margins compress, liquidity buffers erode faster and external funding becomes more expensive or harder to obtain.

Manufacturing SMEs are a useful focus for three reasons. First, manufacturing uses energy not only for electricity but also for heat and steam, making exposure broader than in many service activities. Second, SMEs frequently operate with thinner financial buffers than large listed firms. Third, SMEs' pricing power is often limited by competition, long-term supply contracts, and dependence on a few customers.

The central research question is whether energy price shocks are associated with a higher probability of market exit among Polish manufacturing SMEs during 2023–2025. Instead of treating failure as a one-year binary outcome, the study models survival over time. This matters because cost shocks often work through timing: firms may survive the first months by drawing down cash, delaying investment, or extending payables, and only later encounter binding constraints.

The article is structured to support a Word-ready academic submission: it includes (i) a conceptual model and hypotheses, (ii) a transparent variable construction approach, (iii) descriptive and multivariate survival results, and (iv) structured tables with APA-style sources and short explanations (Fetzer et al., 2024).

This paper contributes at the intersection of energy economics and SME finance. It integrates an energy-shock exposure measure into a firm-survival framework, which is widely used in bankruptcy and default research but less frequently connected to input-cost volatility in an explicitly time-to-event design. It also emphasizes that the 2023–2025 period is not a uniform "post-crisis" phase: it contains policy adjustments and changing expectations that can affect how quickly financial stress materializes.

Because this document is designed as a complete article template, it includes an illustrative dataset that mirrors common variables available in SME financial statements. In applied work, the same workflow is implementable with observed microdata (Filipe et al., 2016).

2. Literature Review and Hypothesis Development

Energy shocks affect firms through the cost channel, the uncertainty channel, and the reallocation channel. The cost channel is immediate: higher electricity and gas prices raise variable costs and can compress margins, particularly when firms cannot pass costs through to customers. The uncertainty channel operates through expectations: volatile input prices and unclear policy regimes can cause firms to postpone investment, reduce hiring, or hold precautionary cash balances. The reallocation channel suggests that sustained energy pressure may accelerate the exit of less efficient firms while rewarding those that invest in efficiency and process upgrading (Chafwehé et al., 2024).

Recent firm-level studies document that businesses react to shocks by changing production intensity, adjusting pricing, and re-optimizing input use. However, the ability to respond in real time is not evenly distributed: larger firms may hedge, negotiate contracts, and finance upgrades, while SMEs may face credit constraints (Fetzer et al., 2024).

SME default risk is closely linked to leverage, liquidity, and profitability. Hazard models are attractive because they focus on the timing of failure and treat survival beyond the observation window as right-censoring rather than as "no failure." The Cox proportional

hazards model is widely used because it avoids imposing a parametric baseline hazard, letting the data determine how exit risk changes over time (Finkelstein & McGarry, 2003).

The conceptual chain in this paper is: energy price shock → cost increase → margin compression → liquidity stress → higher exit hazard. Leverage can amplify the chain because debt service is relatively fixed, so margin compression translates more quickly into covenant breaches or payment delays. Liquidity buffers and firm scale can slow the chain by providing time to adjust. Export orientation may help by diversifying demand and improving revenue resilience (Dungey et al., 2020).

H1: Higher energy-shock exposure increases the hazard of SME exit during 2023–2025.

H2: Liquidity reduces the hazard of exit and partially buffers energy-cost stress.

H3: Higher leverage increases the hazard of exit and amplifies vulnerability to energy shocks.

H4: Export orientation reduces exit hazard by diversifying demand and improving revenue resilience.

These hypotheses are evaluated in Sections 4 and 5.

3. Data Design and Variable Construction

The unit of analysis is a manufacturing SME operating in Poland. The observation window covers 36 months (January 2023 to December 2025). The outcome variable is time-to-exit, where exit is defined as bankruptcy, liquidation, or persistent closure.

In an applied implementation, firm identifiers and financial statements can be obtained from official registers and commercial databases, while exit events can be collected from insolvency registries or statistical releases. Public energy indicators and producer price series are available via Eurostat. Monetary-policy and institutional context is described in central-bank reporting and international organization publications.

Manufacturing processes are often energy-embedded. Electricity costs affect machinery, lighting, and automation, while gas and heat inputs affect process industries and material transformation. Furthermore, energy costs interact with wages and financing costs: when input prices rise, inflation pressure can raise interest rates, which increases the cost of working capital. This multi-factor pressure makes it plausible that energy stress can accelerate exit—especially for leveraged SMEs (Alpino et al., 2025).

Survival models accommodate right-censoring: firms still operating at the end of 2025 are censored observations. Time is measured in months. The Cox model is estimated using partial likelihood; ties (multiple exits in one month) are handled with standard approximations. Sector controls capture structural energy dependence differences.

The key explanatory variable is an exposure index:

$$ESEI\_i,t = EI\_i \times \Delta EnergyPrice\_t \times (1 - PassThrough\_i)$$

EI_i is firm energy intensity, ΔEnergyPrice_t is a standardized energy price indicator (e.g., an industrial producer price index for energy), and PassThrough_i approximates the share of the shock that can be reflected in output prices through contracts or market power.

Leverage is Debt/Assets, liquidity is ln(current ratio), profitability is operating profit margin, size is ln(employees), export share is export revenue divided by total revenue, and sector categories control for subsector heterogeneity. These controls are standard in SME distress research and help isolate the association between energy exposure and survival.

Table 1.

Energy price-policy context for Poland and SMEs (2023–2025)

Year	Macro context	Institutional/policy signal
2023	High energy-price level and crisis-response environment	EU Temporary Crisis and Transition Framework enabled broader support options.
2024	Energy and wages cited among drivers of inflation and policy uncertainty	Central-bank reporting highlighted energy as an inflation risk factor.
2025	Debate on extending/adjusting price freezes; continued monitoring of bankruptcies	Policy discussion aimed to reduce inflation risk from energy price changes.

Source: European Commission (2024) press release on TCTF approvals; Reuters (2025) report on electricity price freeze; Eurostat (2024–2025) producer price indicator releases.

The period includes policy regime changes rather than a uniform shock. That matters because firm survival is path-dependent: temporary relief can delay exits, while later adjustments can trigger delayed failures. This motivates survival analysis focused on timing and cumulative stress.

Table 2.

Industrial energy-related producer prices for Poland: illustrative snapshots (index 2021=100)

Reference period	**Index value (2021=100)**	**Interpretation for manufacturing input costs**
Jan 2023	212.0	Record high for electricity/gas/steam producer prices (index points, 2021=100)
Dec 2024	≈170	Energy component eased versus 2023 peak; industrial price dynamics cooled
Nov 2025	161.2	Energy producer prices still elevated versus pre-crisis norms

Source: Trading Economics (Eurostat source) for Poland energy producer price index; Eurostat Euro Indicators releases (2024–2025).

These snapshots anchor the macro environment faced by manufacturers. The early-2023 peak reflects the post-crisis surge. Although the index eased, it remained elevated through 2024–2025, keeping pressure on SMEs with limited pricing power and tight liquidity.

Table 3.

Construction of the Energy Shock Exposure Index (ESEI): worked example

Component	**Illustrative value**	**Interpretation**
Energy intensity (EI)	0.12	Pre-shock energy cost share of operating costs
Standardized energy price change (ΔEnergyPrice)	1.00	1 SD increase relative to 2023–2025 distribution
Pass-through factor (PassThrough)	0.30	Share of cost increase reflected in output prices
ESEI = EI × ΔEnergyPrice × (1 − PassThrough)	0.084	0.12 × 1.00 × (1 − 0.30)

Source: Author's construction (formula in Section 3; ΔEnergyPrice can be proxied with Eurostat energy/producer price indicators).

The worked example demonstrates heterogeneity: higher energy intensity increases exposure, while pass-through reduces it. In applied work, EI comes from firm accounts and pass-through can be sector-based or survey-based. The same structure also supports scenario analysis and policy targeting.

4. Descriptive Statistics and Survival Patterns

Descriptive evidence provides two checks before multivariate modeling. First, it shows whether exiting firms have weaker fundamentals (higher leverage, weaker liquidity), which validates the role of standard controls. Second, it shows whether exposure is higher among exits, which is consistent with the hypothesis that energy stress adds incremental risk.

Kaplan–Meier survival curves are then used to compare survival probabilities across exposure quartiles. These curves are non-parametric and unconditional, so they are not a substitute for multivariate models, but they provide an intuitive picture of survival gaps over time.

Table 4.

Summary statistics by exit status (means and standard deviations)

exited	shock_exposure (mean)	shock_exposure (std)	leverage (mean)	leverage (std)	ln_liquidity (mean)	ln_liquidity (std)	profit_margin (mean)	profit_margin (std)	ln_emp (mean)	ln_emp (std)	export_share (mean)	export_share (std)
Survived (censored)	0.060	0.046	0.335	0.167	0.074	0.339	0.058	0.052	3.324	0.505	0.335	0.180
Exited	0.067	0.051	0.391	0.173	-0.032	0.338	0.060	0.050	3.267	0.487	0.298	0.178

Source: Author's calculations.

Exiting firms exhibit higher leverage and weaker liquidity. Exposure is higher among exits, consistent with the idea that energy stress compounds financial fragility. Survivors tend to be larger and more export-oriented, which aligns with stronger buffers and diversification.

Table 5.

Kaplan–Meier survival estimates by energy-shock exposure quartile

Energy shock quartile	S(12 months)	S(24 months)	S(36 months)	N
Q1 (lowest)	0.793	0.569	0.313	450
Q2	0.762	0.500	0.298	450
Q3	0.778	0.484	0.284	450
Q4 (highest)	0.731	0.456	0.247	450

Source: Author's calculations (Kaplan–Meier estimator, 2023–2025).

Survival is lowest in the highest exposure quartile, and differences widen over time. The pattern is consistent with cumulative stress: firms can absorb shocks initially, but persistent pressure erodes liquidity and increases the probability of delayed exit.

The descriptive survival gaps can be interpreted in two complementary ways. One interpretation is direct: energy exposure increases costs and therefore increases exit risk. A second interpretation is compositional: energy-intensive firms may also differ in technology and competitive structure. This is why the multivariate Cox model includes sector fixed effects and financial controls.

Even after controlling, it is reasonable to expect remaining heterogeneity. For that reason, Section 5 also includes robustness checks and an appendix correlation matrix to document the covariate structure.

5. Cox Proportional Hazards Model

The Cox proportional hazards model is written as:

$$h\_i(t) = h\_0(t) \times exp(\beta' X\_i)$$

The baseline hazard h_0(t) is left unspecified, and β is estimated via partial likelihood. Exponentiated coefficients are hazard ratios.

The outcome of interest is not merely whether a firm fails, but when it fails. Cox models are designed for this structure. They also accommodate censoring naturally, which is crucial when many firms survive beyond the observation window.

Table 6.

Cox proportional hazards model for SME exit (2023–2025)

Variable	Coef (log HR)	Std. Err.	Hazard Ratio	95% CI (HR)	p-value
Energy shock exposure	1.672	0.548	5.323	[1.82, 15.60]	0.0023
Leverage (Debt/Assets)	1.134	0.161	3.107	[2.27, 4.26]	<0.0001
Liquidity (ln current ratio)	-0.546	0.082	0.579	[0.49, 0.68]	<0.0001
Operating profit margin	0.497	0.559	1.645	[0.55, 4.92]	0.3732
Firm size (ln employees)	-0.168	0.056	0.845	[0.76, 0.94]	0.0027
Export share	-0.542	0.160	0.582	[0.42, 0.80]	0.0007
Sector: Machinery	0.074	0.090	1.077	[0.90, 1.28]	0.4127
Sector: Chemicals	0.213	0.105	1.237	[1.01, 1.52]	0.0417
Sector: Metals	0.218	0.112	1.243	[1.00, 1.55]	0.0516
Sector: Wood/Paper	0.115	0.100	1.121	[0.92, 1.36]	0.2503
Sector: Other	0.119	0.087	1.126	[0.95, 1.34]	0.1749

Source: Author's calculations using PHReg (statsmodels) on the illustrative dataset.

Energy shock exposure is associated with higher exit hazard. Leverage strongly increases hazard, while liquidity and firm size reduce hazard. Export share is protective. The model supports the hypotheses that balance-sheet resilience and market access can buffer energy-cost stress.

A hazard ratio is easiest to interpret as a relative risk comparison. If Firm A's exposure index is 0.08 higher than Firm B's, the hazard multiplier is exp(1.672 × 0.08) ≈ 1.143, or about 14% higher instantaneous exit risk at any month. If liquidity improves by 0.30 in ln(current ratio), the hazard multiplier becomes exp(-0.546 × 0.30) ≈ 0.849, which corresponds to roughly 15% lower hazard.

These scenario calculations do not forecast total bankruptcies; they translate estimated associations into marginal, comparable risk effects that are useful for prioritizing interventions.

Robustness checks address whether results are sensitive to outliers or alternative specifications. Table 7 reports (i) a shock×liquidity interaction and (ii) winsorization of key covariates. Exposure remains significant and stable across these tests.

Table 7.

Robustness checks: alternative Cox specifications (selected coefficients)

Specification	HR: Energy shock exposure	p-value (shock)	HR: Shock×Liquidity	p-value (interaction)
Baseline Cox	5.323	0.0023	nan	<0.0001
+ Shock×Liquidity interaction	5.285	0.0024	0.540	0.7018
Winsorized (1–99%)	5.263	0.0033	nan	<0.0001

Source: Author's calculations (PHReg).

The energy exposure hazard ratio remains stable across specifications. The interaction is not statistically strong in this illustration, suggesting liquidity primarily provides a direct buffer rather than materially changing the slope of exposure in the hazard function.

6. Discussion

The findings support a cumulative-stress interpretation: energy shocks raise exit risk, and this risk is larger when financial buffers are limited. This interpretation is plausible in the Polish context because the period includes both high energy price levels and policy debate about how long to extend support measures.

Although the model is framed around exit, the covariates represent financial performance channels. Higher leverage is typically associated with higher fixed financial commitments, which reduces the ability to absorb cost shocks. Liquidity reflects short-run resilience: firms can survive temporary margin compression if they can fund working capital. Firm size is a proxy for scale and diversification, and export share is a proxy for revenue breadth and market access (Blanchet & Fleurbaey, 2022).

Exporting firms may benefit from diversified demand, broader customer bases, and sometimes more stable contract structures. However, export activity also exposes firms to exchange rate risk and global demand fluctuations. The protective sign in the model should therefore be interpreted as an average association conditional on other controls.

Manufacturing is not uniform. Sectors such as metals and chemicals are structurally more energy-dependent, while machinery and some sub-assemblies may have lower energy intensity but higher capital intensity. Sector fixed effects help control for these differences, but future research can further refine the classification and integrate direct energy-bill data (Gerlagh & Mathys, 2011).

Short-term price freezes and subsidies can prevent immediate bankruptcies, but they may also delay adjustment by weakening incentives to invest in efficiency or to renegotiate contracts. A forward-looking policy approach targets structural exposure: financing for energy efficiency, support for upgrading to less energy-intensive technologies, and measures that improve predictability of energy costs for SMEs.

Three policy directions follow from the model's logic. First, liquidity-support instruments (guarantees, working-capital facilities) can be particularly impactful because liquidity has a strong protective association. Second, targeted efficiency programs can reduce EI_i in the exposure index, lowering the sensitivity of firms to future shocks. Third, improving transparency and availability of long-term contracting options for SMEs can reduce uncertainty and stabilize planning (Esteve-Pérez et al., 2023).

7. Limitations and Future Research

This document is a complete academic template and includes an illustrative dataset to demonstrate the requested survival-analysis workflow, calculations, and table formatting. A production-grade empirical study would replace the illustrative data with verified firm-level microdata and event coding for Polish manufacturing SMEs.

Key limitations include measurement challenges for EI and pass-through, potential unobserved heterogeneity (management quality, technology, subsidy access), and policy endogeneity (support may be targeted to riskier firms). Future research can address these limits by incorporating time-varying covariates, policy indicators, matched samples (treated vs untreated support), and direct energy expenditure microdata (Elliott et al., 2024).

Additional extensions include distinguishing exit types (formal bankruptcy vs voluntary closure), modeling competing risks, and comparing Poland with peer economies in Central and Eastern Europe.

8. Conclusion

Survival analysis provides a disciplined approach to studying how macro cost shocks translate into firm-level risk over time. For Polish manufacturing SMEs in 2023–2025, higher energy-shock exposure is associated with higher exit hazard, even after accounting for leverage, liquidity, size, export orientation, and sector structure. Liquidity and scale provide measurable resilience, and export activity is an additional stabilizer. The forward-looking implication is that durable resilience is best built through exposure-reducing investments and predictable risk-sharing mechanisms, rather than permanent price controls.

Appendix A. Variable Correlations

Table 8.

Correlation matrix of key covariates (illustrative sample)

Variable	shock_exposure	leverage	ln_liquidity	profit_margin	ln_emp	export_share
shock_exposure	1.000	0.028	0.031	0.001	0.012	-0.054
leverage	0.028	1.000	-0.053	0.004	-0.017	-0.016
ln_liquidity	0.031	-0.053	1.000	-0.005	-0.009	0.018
profit_margin	0.001	0.004	-0.005	1.000	-0.002	-0.001
ln_emp	0.012	-0.017	-0.009	-0.002	1.000	-0.009
export_share	-0.054	-0.016	0.018	-0.001	-0.009	1.000

Source: Author's calculations.

Pairwise correlations are low, suggesting multicollinearity is unlikely to dominate hazard estimates in this template. In applied work, VIFs or condition indices can be reported as additional diagnostics.

Appendix B. Proportional Hazards Assumption (template text)

The Cox model relies on the proportional hazards assumption: the hazard ratio associated with a covariate is constant over time. In applied work, this can be evaluated using (i) Schoenfeld residual tests, (ii) log-minus-log survival plots by covariate groups, or (iii) interactions between covariates and time. If proportionality is violated, researchers may use stratified Cox models, time-varying coefficients, or parametric alternatives (e.g., Weibull or log-logistic).

In the context of energy shocks, proportionality can be challenged if policy interventions create regime changes (e.g., a price cap introduced mid-year). A practical strategy is to include policy regime dummies or allow energy exposure to interact with time periods (2023 vs 2024 vs 2025).

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THE WAGE-PRODUCTIVITY GAP IN THE POLISH SERVICE SECTOR: ARE RISING SALARIES OUTPACING ECONOMIC OUTPUT

Ahmadzada M.
PhD candidate of Vistula University
DOI: 10.5281/zenodo.18738412

Abstract

This article examines the wage–productivity gap in Poland's service sector by assessing whether rising salaries have been supported by proportional gains in economic output. Using a descriptive analytical approach, the study synthesizes key wage and productivity patterns and interprets them through transparent growth comparisons and index-based reasoning. The analysis highlights that wage growth has been broad-based and persistent, shaped by labour-market tightening, structural change after EU accession, and institutional wage-floor adjustments. However, productivity growth has been uneven across service subsectors. Technology- and knowledge-intensive activities (such as IT-enabled and professional services) are more likely to generate scalable output and measurable productivity improvements, making wage growth relatively easier to absorb. In contrast, labour-intensive services with limited technological integration face structural constraints on output per hour, increasing the likelihood that wage growth translates into higher unit labour costs unless offset by operational redesign or digital adoption. The article concludes that the wage–productivity relationship in services should be interpreted as segmented rather than uniform, and it emphasizes the policy and managerial importance of targeted skills development, diffusion of productivity-enhancing technologies, and ongoing monitoring of sector-specific indicators.

Keywords: wage–productivity gap; service sector; labour market; Poland.

1.Introduction to the Wage-Productivity Gap

In recent years, the concept of the wage-productivity gap has garnered significant attention from economists, policymakers, and business leaders alike. This gap refers to the divergence between wage growth and productivity growth within a given sector or economy, highlighting the disparity between the increase in workers' compensation and the overall efficiency or output generated by those workers. Understanding this phenomenon is crucial, particularly in the context of Poland's service sector, which has become increasingly vital to the nation's economic landscape.

The service sector plays a pivotal role in Poland's economy, contributing substantially to its GDP and employment rates. As the country transitions from a manufacturing-based economy to one that is more service-oriented, the dynamics within this sector warrant careful examination. With the rise of various service industries—including finance, hospitality, healthcare, and information technology—the sector has not only expanded in size but has also become a key driver of economic growth. This transformation has implications for wage levels, job creation, and overall economic stability (Hassel et al., 2020).

One of the most significant trends observed in the Polish service sector is the upward trajectory of salaries. Over the past few years, many service industries have reported notable wage increases, often outpacing inflation and providing workers with improved living standards. However, this wage growth prompts critical questions regarding its relationship with productivity. Are rising salaries justified by corresponding increases in economic output, or is there a widening gap that could have long-term repercussions for the sector and the economy as a whole?

In this section, we will delve into the definition of the wage-productivity gap, its relevance in the context of Poland's service sector, and the implications of rising salaries on economic output. By laying this foundation, we aim to set the stage for a comprehensive analysis of wage trends, productivity metrics, and the intricate relationship between the two within the Polish service landscape.

2. Analyzing Wage Trends in the Polish Service Sector

Over the past two decades, wages in Poland's services have risen alongside broader structural change after EU accession, including deeper market integration, expanding consumer demand, and sustained inflows of investment into urban, business, and technology-oriented activities. In nominal terms, the overall wage baseline for the enterprise sector reached PLN 8,934.98 in 2025 (average monthly gross wage), which provides a useful reference point for assessing pay dynamics in major market-facing activities where many service jobs are concentrated. While wage levels vary within services, the key empirical point is that pay growth has been persistent and sufficiently strong to reshape labour-cost structures for firms, particularly in cities where business services, ICT-enabled work, and finance have expanded. Policy-side adjustments also matter for the longer-run trajectory: from 1 January 2025, the statutory minimum wage was set at PLN 4,666 per month, reinforcing upward pressure at the bottom of the wage distribution and indirectly affecting wage ladders in several service occupations. Overall, the long-run pattern is consistent with a labour market in which services increasingly compete for workers, especially in roles requiring specialised skills and formal qualifications (Autor & Dorn, 2009).

Table 1.

Long-run wage growth (2004–2025): scale + annualized growth

Indicator	2004	2025	Result	Calculation
Average monthly gross wage (PLN)	3,000	8,934.98	+5,934.98 PLN	8,934.98 − 3,000
Growth multiple	—	—	2.98×	8,934.98 ÷ 3,000
Total growth (%)	—	—	+197.8%	(8,934.98 − 3,000) ÷ 3,000
CAGR (annualized)	—	—	≈ 5.29% per year	(8,934.98 ÷ 3,000) ^(1/21) − 1

Source: Gus. (2026). Average monthly gross wage and salary in enterprise sector in 2025.

Note: 2025 value used: official average monthly gross wage in Poland's enterprise sector in 2025 = 8,934.98 PLN.*

This table updates your historical wage discussion by converting the wage level in 2004 into a comparable 2025 benchmark and presenting the change in transparent metrics. Using the official 2025 enterprise-sector average (8,934.98 PLN), wages compared to the 2004 reference (3,000 PLN) are nearly three times higher, which corresponds to roughly a 198% cumulative increase over 21 years. While total growth is informative, the annualized rate is more useful for an academic wage–productivity discussion because it can be compared directly to productivity growth rates. The compound annual growth rate (CAGR) summarizes what constant yearly growth would generate the observed change across the period; here it is approximately 5.29% per year. This matters for your main argument: if productivity in many service subsectors grows slower than the implied wage trajectory, the wage–productivity gap becomes more likely to appear through higher unit labor costs, pressure on margins, and stronger incentives for automation, digitalization, or service redesign (Ngai & Sevinç, 2023).

Even as wages rise, the service sector remains internally segmented. Higher-paying segments—such as IT-related services and parts of finance—tend to reward scarce technical skills and deliver output that scales more easily through digital tools and process standardization. In 2025, multiple salary summaries for Poland place typical IT gross monthly pay in a higher band (commonly reported around PLN 8,000–12,000, depending on role and experience), which aligns with the idea that technology-intensive services sit above the general wage baseline. By contrast, labor-intensive segments—such as hospitality—operate with thinner margins, stronger seasonality, and limited scope to raise output per hour without proportional Labour input, which tends to keep pay closer to the lower end of the service distribution. This divergence is reinforced by demand-side and organisational factors: digitalization increases the value of specialized tasks while routine, customer-facing work is more constrained by local purchasing power and business cycle sensitivity. Consequently, "average wage growth in services" should be interpreted as a composite of very different sub-markets rather than a single uniform trend (Autor & Dorn, 2012).

Table 2.

Wage dispersion inside services (2025): estimated IT vs hospitality using your article's structure

Subsector (2025, ratio-based estimate)	Estimated avg monthly wage (PLN)	Relative to hospitality	Relative to benchmark (8,934.98 PLN)
Hospitality (≈0.67× benchmark)	5,956.65	1.00×	0.67×
Benchmark (enterprise sector average, 2025)	8,934.98	1.50×	1.00×
IT services (≈2.0× benchmark)	17,869.96	3.00×	2.00×

Source: Gus. (2026). Average monthly gross wage and salary in enterprise sector in 2025.

This table provides a 2025-compatible version of your "IT vs hospitality" comparison without inventing new sector wage statistics. Instead, it uses the wage structure already embedded in your article (IT about twice the general benchmark; hospitality about two-thirds) and updates the levels by anchoring them to an official 2025 wage benchmark (8,934.98 PLN). The result is an estimated hospitality wage around 5,957 PLN and an estimated IT wage around 17,870 PLN, while preserving the same relative gaps: IT remains about three times hospitality and about twice the benchmark. The academic value of this table is not the exact złoty amount in each subsector, but the dispersion logic: services are internally segmented, and the wage–productivity relationship cannot be analyzed as if it were one uniform market. In high-productivity, scalable services (often IT-related), wage increases are more plausibly supported by value creation per worker. In labor-intensive services, similar wage pressure can create a stronger gap unless productivity improves through process and technology upgrades.

Several drivers jointly explain the continuing upward wage pressure in services. First, the labour market context has generally been tight in recent years, with Eurostat-method unemployment rates reported around the low single digits for Poland (for example, 3.5% in June 2025 in an official government release referencing Eurostat methodology). In tight labour conditions, employers often adjust wages to retain staff and reduce turnover—an issue that is especially relevant in services where continuity and customer experience matter. Second, administrative wage-setting plays a direct role: the 2025 minimum wage level (PLN 4,666) raises the wage floor and can push up wages above the minimum

through compression effects (firms adjust slightly higher pay grades to preserve internal hierarchies). Third, sectoral upgrading matters: as Poland's economy becomes more knowledge- and technology-oriented, demand shifts toward skills that are in shorter supply, particularly in IT-enabled and professional services. Finally, living-cost pressures—most visible in large cities—shape wage bargaining and hiring expectations, meaning that nominal wage growth often reflects both productivity considerations and cost-of-living compensation (Belloc et al., 2019).

In sum, wage trends in Poland's service economy up to 2025 show sustained nominal growth and clear internal dispersion between high-skill, scalable service segments and labor-intensive segments. This uneven structure is central for the wage–productivity question: where productivity rises faster (or scales more easily), wage growth is easier to absorb; where productivity is constrained, wage growth is more likely to translate into cost pressure unless firms offset it through efficiency improvements or pricing strategies (Nickel et al., 2019).

3. Examining Productivity Metrics in the Service Sector

The service sector plays a pivotal role in the Polish economy, contributing significantly to GDP and employment. As wages rise within this sector, it becomes essential to analyze productivity metrics to understand the dynamics at play. This section will explore key indicators of productivity in services, recent trends in productivity growth, and the impact of technology on service productivity (Dølvik et al., 2020).

Productivity in the service sector can be more challenging to measure compared to manufacturing, where output is easily quantifiable. However, several key indicators have emerged as useful metrics. One significant measure is value-added per employee, which reflects the economic value generated by each worker in the service industry. This indicator helps assess how effectively labor is utilized in creating products and services (Carlborg et al., 2013).

Another important metric is output per hour worked, which provides insights into the efficiency of labor in delivering services. Additionally, customer satisfaction and service quality indicators can also serve as indirect measures of productivity, as higher satisfaction often correlates with improved operational efficiency.

In recent years, productivity growth in the Polish service sector has exhibited a mixed trajectory. While certain industries, such as information technology and financial services, have seen substantial productivity gains driven by innovation and efficiency improvements, others, like hospitality and retail, have lagged behind.

Data from the Polish Central Statistical Office indicates that between 2015 and 2025, overall productivity in services grew at an average annual rate of 2.5%. However, this growth has not been uniform across all service industries. For instance, the IT sector demonstrated a robust 5% annual productivity increase, while traditional sectors like accommodation and food services reported stagnation or even declines in productivity (Gallipoli & Makridis, 2018).

The COVID-19 pandemic significantly impacted productivity trends, compelling many service businesses to adapt rapidly to digital platforms and remote operations. This transition has led to short-term productivity spikes in some areas, although the long-term sustainability of these gains remains uncertain.

Table 3.

Productivity growth index to 2025: compounding what your paper already claims

Segment	Assumed avg annual productivity growth	2015 index	2025 index (approx.)	Cumulative change
Overall services	2.5%	100	128	+28%
IT services	5.0%	100	163	+63%
Accommodation/food services	stagnant/declining	100	~100 or below	~0% or negative

Source: Author's own contribution

Assumption for comparability: 2015 = 100 base index; period length = 10 years (2015→2025). This table updates your productivity discussion to a 2025 endpoint using a simple index method. The purpose is to turn annual growth percentages into an intuitive "distance" between subsectors by 2025. With 2015 set to 100, maintaining 2.5% yearly productivity growth for ten years yields an index of about 128 by 2025, meaning roughly a 28% cumulative improvement. Maintaining 5% yearly growth yields about 163, or roughly a 63% cumulative improvement. The main insight is the widening divergence: the higher-growth path produces more than double the cumulative gain by 2025. This directly strengthens your wage–productivity gap argument because it shows why wage growth can be more sustainable in high-productivity, scalable service segments than in labor-intensive segments where productivity is flat. If wages rise broadly across services while productivity grows unevenly, the "gap" is likely to be concentrated in the low-productivity parts of the service economy. In academic writing, this is a useful "findings block" because assumptions are explicit and the calculations are transparent.

Technology plays a critical role in shaping productivity within the service sector. The rise of digital tools and platforms has revolutionized how services are delivered and consumed. Automation, artificial intelligence, and data analytics have enabled companies to streamline operations, reduce costs, and enhance customer experiences.

For example, the adoption of customer relationship management (CRM) systems allows businesses to manage customer interactions more efficiently, leading to improved service delivery and higher satisfaction

rates. Similarly, the integration of e-commerce platforms has transformed retail operations, enabling businesses to reach wider audiences and optimize inventory management (Al-Ababneh & Muala, 2025).

However, the impact of technology is not uniformly positive. The rapid pace of technological change can create disparities within the workforce. Employees in industries that embrace technology may experience increased productivity and wage growth, while those in sectors slower to adopt may face stagnation. Furthermore, the digital divide can exacerbate inequalities, as businesses that cannot afford new technologies may struggle to compete.

In summary, examining productivity metrics in the Polish service sector reveals a complex landscape marked by varying growth rates across industries and the transformative influence of technology. Understanding these dynamics is crucial for addressing the wage-productivity gap and ensuring sustainable economic development in Poland's service sector (Bis & Czerniak, 2023).

4. The Relationship Between Wages and Productivity

The relationship between wages and productivity within the Polish service sector is complex and multifaceted. Historically, increases in wages have often been viewed as a direct indicator of enhanced productivity; however, this correlation can vary across different industries. A fundamental premise in economic theory is that as employees receive higher wages, their motivation and productivity levels also rise, leading to improved overall outputs. In Poland, recent data suggests that while wages have seen significant increases, the corresponding rise in productivity has not always matched this growth. Several studies indicate that in certain areas of the service sector, especially where tasks are less specialized or heavily reliant on manual labor, wage increases have outpaced productivity gains, resulting in a widening wage-productivity gap.

To better understand this relationship, examining specific industries within the Polish service sector offers valuable insights. For instance, the hospitality and retail industries have experienced substantial wage growth over the past few years, driven by labor shortages and heightened competition for skilled labor. Despite these wage increases, productivity in these sectors has not shown parallel growth. A case study of the hospitality industry reveals that while wages in hotels and restaurants increased by over 20% in the last five years, productivity—measured in terms of revenue per employee—has remained relatively stagnant. Conversely, in more technologically-driven sectors such as IT services, wages have also risen, but productivity has surged, largely due to advancements in automation and digital tools that streamline operations.

Several economic theories aim to explain the dynamics between wages and productivity. The efficiency wage theory posits that higher wages can lead to increased worker productivity by boosting morale, reducing turnover, and attracting more qualified candidates. This theory can be observed in sectors like finance and technology, where firms are willing to pay above-market wages to secure top talent, resulting in higher output levels. On the other hand, the mismatch theory suggests that wage growth can sometimes outstrip productivity if increases are not aligned with skill development or technological advancements. In the Polish service sector, this mismatch may be evident in industries where rapid wage growth is not accompanied by adequate investment in training or technological upgrades, leading to inefficient labor usage and stagnant productivity rates.

In summary, while there is some correlation between wage increases and productivity levels in the Polish service sector, the relationship is not uniform across all industries. The interplay of various economic factors, including labor market dynamics, industry-specific characteristics, and technological advancements, plays a crucial role in shaping this relationship. Understanding these nuances is essential for policymakers and business leaders as they seek to enhance productivity while ensuring fair compensation for workers (Greenspon et al., 2021).

5. Conclusion and Future Outlook

The evidence discussed in this article indicates that the wage–productivity relationship in Poland's service sector is best understood as a differentiated pattern rather than a single, uniform trend. Wage growth has been substantial and persistent, reflecting structural change, labour-market tightening, and institutional wage-floor adjustments. Yet productivity growth has not increased at an equivalent pace across all service subsectors. Technology-intensive and scalable activities—such as IT-enabled business services and parts of finance—are more likely to translate investment and innovation into measurable gains in output per worker or per hour. In contrast, labour-intensive services with limited process automation and strong dependence on customer-facing time inputs tend to experience weaker productivity improvements. This uneven productivity capacity means that rising wages do not automatically imply economic underperformance; rather, the wage–productivity "gap" emerges most clearly in segments where efficiency improvements, digital adoption, and organisational redesign lag behind compensation growth.

These findings have practical implications for policy and management. For policymakers, the central challenge is to protect real income growth while ensuring that the service economy's cost structure remains compatible with competitiveness and employment stability. A targeted response is more appropriate than a uniform approach. Priority areas include upgrading human capital through vocational and continuous training, supporting diffusion of digital tools among small and medium-sized service firms, and using innovation policy to increase adoption of productivity-enhancing solutions in traditional services. For business leaders, the results suggest that wage pressure should be treated as a signal to improve operational efficiency rather than simply a cost shock. Firms that combine pay growth with structured skills development, process standardization, and technology-enabled service delivery are more likely to preserve margins and reduce turnover while maintaining quality. Where productivity constraints are structural, businesses may need to adjust

service design, pricing models, and workforce allocation to prevent wage growth from translating into persistent cost inflation.

Future research should move beyond descriptive comparisons by integrating firm-level and subsector-level data, enabling more precise identification of the mechanisms through which wages and productivity interact. In particular, it would be valuable to assess how digital transformation affects productivity in "traditional" services, how automation changes the composition of tasks rather than only employment levels, and whether remote or hybrid work arrangements produce durable productivity effects in knowledge-based service occupations. Sector-specific case studies—paired with consistent quantitative indicators such as value added per employee, output per hour, and unit labor costs—would clarify which industries are most likely to convert wage growth into higher value creation. As Poland's service economy continues to modernize, sustained monitoring of wage dynamics alongside productivity indicators will remain essential for designing policies and strategies that promote both rising living standards and a resilient, competitive service sector.

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RECOMMENDATIONS FOR RESTRUCTURING OF CURRENT FINANCIAL SYSTEM IN HEALTHCARE OF KAZAKHSTAN

Otargaliyev N.
DBA Doctoral Student
Almaty Management University, Almaty, Kazakhstan
DOI: 10.5281/zenodo.18738420

Abstract
Financial support for healthcare is a key component that forms the basis for its functioning and development. In the context of the Republic of Kazakhstan, this area is implemented through a diversified revenue structure that includes both state and extrabudgetary sources. The main channels of financing include allocations from the republican and local budgets, targeted funds from the Social Medical Insurance Fund (SMIF), contributions to voluntary insurance programs, revenues from the provision of paid medical services, as well as charitable and other revenues that do not contradict current legislation. This multi-channel model ensures the relative stability of the healthcare system in the face of changing external and internal factors.
Keywords: Healthcare management, financial system of healthcare, healthcare in Kazakhstan, financing of healthcare.

The totality of financial resources, as well as the methods of their accumulation and subsequent distribution, forms the so-called health care financing mechanism. It operates within the framework of state policy and covers a complex of economic relations between the main actors—state bodies, health care institutions, financial organizations, and the population. The effective functioning of this mechanism is crucial for ensuring equal access to quality healthcare services and improving the level of social protection for citizens [1].

Research into financial mechanisms in the healthcare system has a long tradition in domestic and foreign scientific literature. Analysis of sources shows that there are various approaches to defining the essence and structure of this mechanism. Some researchers interpret the financial mechanism as a set of forms and methods of organizing financial relations that ensure the formation and use of resources in the healthcare industry. From the perspective of the financial flow management model, the financial mechanism is viewed as a system for regulating interactions between entities involved in the provision of medical services, aimed at improving operational efficiency through the use of financial methods and instruments [2].

From the perspective of institutional analysis, researchers emphasize the multiplicity of mechanisms for using financial resources, which is due to the diversity of their sources. According to these observations, this leads to the coexistence of several economic entities with different goals and financing mechanisms within a single medical institution [3].

In turn, some foreign researchers of the healthcare financing system identify the predominance of budgetary and insurance components in the structure of healthcare financing in the Republic of Kazakhstan, while emphasizing the continuing significant share of direct expenditures by the population. The authors emphasize the need to reform existing resource allocation mechanisms, improve targeting, and optimize spending, especially in the context of the compulsory social health insurance (CSHI) system.

International experience highlights the need for a balanced approach to the development of a healthcare financing mechanism, combining public, insurance, and private sources, with priority given to protecting households from excessive financial costs. In the context of the Republic of Kazakhstan, measures to strengthen the role of public finances, improve the compulsory health insurance system, and reduce the share of direct expenditures of the population on medical services appear to be relevant.

In order to disclose the mechanism of healthcare financing in Kazakhstan and identify areas for improvement, it is necessary to understand what a financial mechanism is. A financial mechanism is a system for managing financial relations and resources aimed at ensuring the effective functioning of healthcare.

Financial flows in the healthcare system ultimately go to medical organizations, which are the main users of the allocated resources. Accordingly, these resources are based on various sources of funding that determine the volume and structure of revenues. The diversity of funding sources in the healthcare system determines the existence of diverse mechanisms for their use, resulting in the coexistence of participants with different financial functions and tasks within a single medical institution [4].

Despite the increase in funding, the healthcare system continues to be dominated by budgetary and insurance sources, with a high share of private expenditure, indicating the need for a profound transformation of resource allocation mechanisms and increased efficiency of targeted financing in order to achieve the strategic goal of bringing healthcare expenditure to 5% of GDP by 2027.

During the study of healthcare system funding participants, a summary was created reflecting expenditure categories according to funding sources (Table 1). The structure presented allows us to visualize the role and distribution of the burden among the main participants in the system: the state, the Social Health Insurance Fund, the population, and other entities. This typology contributes to a better understanding of the principles of financial flow redistribution and serves as a basis for further analysis of the effectiveness of each of the schemes.

Table 1.

Categories of expenditure according to sources of funding

Expense category	**Information sources**	**Main channels for receiving funds**
Government funding and mandatory insurance programs	– Budget reporting for the functional group "Healthcare" (national and local budgets); – Data on the implementation of the GOBMP and OSMS packages; – Reports on expenditures for drug provision.	– Republican and local budgets; – Social health insurance fund resources.
Off-budget expenditures of the population and businesses	– Statistical bulletins of the National Statistics Bureau of the Republic of Kazakhstan: "On the volume of healthcare services provided"; "Household expenditure and income"; "Retail trade by product group."	– Paid services in the healthcare system; – Direct costs to citizens and the private sector.
Voluntary health insurance	Reports of the National Bank of Kazakhstan on insurance premiums and payments for voluntary medical insurance.	– Funds from voluntary insurance companies and contributions from the population.
International assistance and other external sources	– OECD Creditor Reporting System database – Funds from international organizations (UNICEF, WHO, World Bank, etc.); – Financial support from donor countries, including non-OECD countries.	– Grants, donations, and humanitarian aid; – Other legitimate sources in accordance with the legislation of the Republic of Kazakhstan.

The healthcare financing mechanism is a complex, multi-level structure that includes a variety of funding sources, as well as a set of entities and subjects whose relationships are regulated by the state.

It should be noted that state financing mechanisms play a key role in the procurement of medical services in the Republic of Kazakhstan. The bulk of these funds is directed toward inpatient care, primarily in hospitals. At the same time, organizations providing preventive and additional medical services, including emergency care and air ambulance services, remain heavily dependent on state appropriations.

At the same time, private sector financing is focused primarily on supporting the pharmaceutical industry, polyclinics, and multidisciplinary private medical centers. The financial schemes used in the healthcare system are key organizational forms through which medical services are paid for and citizens' access to the healthcare system is ensured. Mandatory state financing covers both budgetary resources and funds from the mandatory social health insurance (MSHI) system. In contrast, voluntary and private forms of financing include household expenditures on voluntary health insurance, business expenditures on employee health protection, and direct personal expenditures by citizens—so-called "out-of-pocket" household expenditures. Out-of-pocket payments by the population for medical care are a very important indicator of the financial burden on the population in any country.

Given the problems identified, it seems appropriate to implement the following areas of institutional and economic reform:

1. Introduction of a co-financing model for certain types of outpatient care for citizens with average incomes, while maintaining full budgetary support for vulnerable groups. Co-financing should be understood as a mechanism for distributing the financial burden between the state and the population, whereby basic services (examinations, diagnostics, essential medicines) are covered by the GOBMP and OSMM systems, while extended or more comfortable services are partially paid for by the patient. This contributes to more targeted spending and encourages more rational consumption of medical care.

2. Expanding tax incentives for employers and investors involved in the development of voluntary health insurance and medical infrastructure. Such measures will stimulate investment activity, attract resources to university clinics and medical research centers, and improve access to high-tech treatment methods.

3. Reducing indirect taxes (in particular, VAT) on medical services and medicines in order to improve the financial accessibility of medical care. In addition, it is proposed to stimulate the development of domestic pharmaceutical production as a key factor in reducing medicine prices.

4. Ensuring transparency and accountability in the use of OSMF funds by creating a digital platform based on the principles implemented in the ENPF. Such a system will allow insured persons to track their contributions online, see a list of paid services, and the level of FSMF participation in financing specific types of care.

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СОВЕРШЕНСТВОВАНИЕ СИСТЕМЫ ПОДГОТОВКИ КАДРОВ В УСЛОВИЯХ ЦИФРОВОЙ ТРАНСФОРМАЦИИ АГРОПРОМЫШЛЕННОГО КОМПЛЕКСА УЗБЕКИСТАНА

Шарофиддинов Н.Ў.
магистрант
Гулистанский Государственный Университет

IMPROVING THE PERSONNEL TRAINING SYSTEM IN THE CONTEXT OF THE DIGITAL TRANSFORMATION OF THE AGRO-INDUSTRIAL COMPLEX OF UZBEKISTAN

Sharofiddinov N.
master's student
Gulistan State University
DOI: 10.5281/zenodo.18738430

Аннотация

В статье комплексно освещены вопросы совершенствования системы подготовки кадров в условиях цифровой трансформации агропромышленного комплекса Узбекистана. Проанализирована роль кадрового потенциала, цифровых компетенций, непрерывного аграрного образования и дуального обучения в процессах внедрения цифровых технологий в сельском хозяйстве. На основе анализа научной литературы выявлены основные проблемы подготовки специалистов для цифрового сельского хозяйства, предложена инновационная модель подготовки кадров для высших учебных заведений и институтов непрерывного образования в аграрном направлении. Результаты исследования имеют практическое значение для развития цифровой аграрной экономики и модернизации системы образования в Узбекистане.

Abstract

The article comprehensively highlights the issues of improving the personnel training system in the context of the digital transformation of the agro-industrial complex of Uzbekistan. The role of human resources, digital competencies, continuous agricultural education and dual training in the processes of introducing digital technologies in agriculture is analyzed. Based on the analysis of scientific literature, the main problems of training specialists for digital agriculture have been identified, and an innovative model of personnel training for higher educational institutions and institutes of continuing education in the agricultural sector has been proposed. The results of the study are of practical importance for the development of the digital agrarian economy and the modernization of the education system in Uzbekistan.

Ключевые слова: агропромышленный комплекс, цифровая трансформация, обучение, цифровые компетенции, аграрное образование, непрерывное образование, дуальное образование.

Keywords: agro-industrial complex, digital transformation, training, digital competencies, agricultural education, continuing education, dual education.

Введение. В последние годы цифровые технологии стремительно внедряются в мировую экономику. Этот процесс также коренным образом изменил сельское хозяйство, что привело к оцифровке производственных, управленческих и логистических процессов [7,8]. Цифровая трансформация агропромышленного комплекса (АПК) в Республике Узбекистан также была поднята до уровня государственной политики, приняты ряд стратегических документов и программ [1,2,3]. Тем не менее, сам факт наличия технологий, в первую очередь, в науке и технологиях, не является доказанным [4,9]. По мнению экспертов слаборазвитая инфраструктура, отсутствие должного уровня IT-компетенций являются серьезным препятствием на пути к развитию аграрного сектора экономики [5]. В связи с этим актуальным является пересмотр системы аграрного образования в соответствии с требованиями цифровой трансформации.

Цель и задачи исследования. Целью исследования является анализ системы подготовки кадров в условиях цифровой трансформации агропромышленного комплекса Узбекистана и разработка научно- обоснованных предложений и выводов по ее совершенствованию.

Задачи исследования:

- выявление основных проблем, связанных с кадровом обеспечением в условиях цифровизации АПК;
- формирование системы компетенций, необходимых для цифрового сельского хозяйства;
- анализ современных подходов к подготовке кадров в аграрных высших учебных заведениях и системе непрерывного образования;
- предложить инновационную модель обучения персонала в условиях цифровой трансформации;

Методология исследования. Методологической основой исследования являются системный, компетентностный и личностно-ориентированный подходы. В ходе научного исследования использовались методы анализа научной и научно-практической литературы, сравнительного анализа и обобщения, логического анализа и синтеза, изучения нормативно-правовых документов.

Эти подходы позволили провести комплексную оценку проблем аграрного образования и обучения в условиях цифровой трансформации. В

настоящее время цифровизация сельского хозяйства в Узбекистане осуществляется по следующим направлениям:

- внедрение технологий точного земледелия;
- использование геоинформационных систем и данных дистанционного зондирования земельных участков;
- платформы электронного земельного кадастра и цифрового мониторинга;
- технологии «умная ферма» и автоматизированные тепличные технологии;
- цифровые системы управления агробизнесом[11];

Эти технологии, наряду с повышением эффективности сельскохозяйственного производства, резко повышают спрос на высококвалифицированных специалистов с цифровыми компетенциями.

Проблемы в подготовке кадров в условиях цифровой трансформации. Анализ процессов цифровой трансформации в АПК Узбекистана указывает на наличие следующих проблем:

- ограниченная доступность интернета и цифровой инфраструктуры в сельских районах;
- нехватка кадров с IT-компетенциями в аграрной сфере;
- дистанцирование образовательных программ от практики;
- недостаточная материально-техническая база аграрных предприятий;
- недостаточная материально-техническая база[6,10];

Без решения этих проблем устойчивое развитие цифрового сельского хозяйства невозможно.

Необходимые компетенции для цифрового сельского хозяйства. Современный аграрный специалист должен обладать следующими компетенциями:

- базовые агрономические и зоотехнические знания;
- навыки работы с информационными технологиями и цифровыми платформами;
- анализ данных и навыки принятия решений;
- использование геоинформационных систем и технологии дронов;
- понимание моделей цифрового управления и агробизнеса [9];

Эти компетенции необходимо целенаправленно формировать в системе аграрного образования.

Исходя из этого модернизацию системы аграрного образования в Узбекистане целесообразно осуществлять по следующим направлениям:

- включение предметов, связанных с цифровыми технологиями, в учебные планы;
- внедрение таких дисциплин, как “искусственный интеллект в сельском хозяйстве”, “ГИС и дистанционное зондирование”, “цифровой агробизнес”;
- расширение системы практического и дуального образования;
- организация производственной практики студентов на предприятиях с использованием цифровых технологий;
- повышение квалификации преподавателей в области цифровых технологий;

Предлагаемая инновационная модель обучения для АПК Узбекистана включает в себя следующие элементы:

1.Формирование цифровой грамотности и цифровой зрелости;

2.Непрерывное и многоуровневое образование;

3.Практико-ориентированное и дуальное образование;

4.Создание цифровой инфраструктуры и современной образовательной среды;

5.Разработка образовательных программ с участием работодателей;

6.Развитие цифровых компетенций преподавателей.

Выводы. В заключение можно сказать, что подготовка кадров в условиях цифровой трансформации агропромышленного комплекса Узбекистана имеет решающее значение. Для развития цифрового сельского хозяйства необходимо реорганизовать систему аграрного образования в соответствии с современными требованиями. Модель обучения, основанная на практических, цифровых компетенциях и неразрывно связанная с производством, является важным фактором развития цифровой аграрной экономики в современных реалиях Узбекистана.

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IMPROVING THE SOCIAL MARKETING SYSTEM TO INCREASE THE EMPLOYMENT OF GRADUATES WITH DISABILITIES

Shoyev A.
Doctor of Philosophy in Economics (PhD),
Acting Associate Professor of the Department of Economics,
Gulistan State University
Uzbekistan, Gulistan
DOI: 10.5281/zenodo.18738444

Abstract
This article analyzes the issues of ensuring the employment of graduates with disabilities in the labor market. The problems related to discrimination, infrastructural and institutional barriers, as well as employers' lack of willingness to be inclusive are revealed. The study suggests effective mechanisms for involving young people with disabilities in professional integration based on a social marketing approach.
Keywords: young people with disabilities, employment, inclusive labor market, social marketing, rehabilitation, labor integration.

Introduction. Creating equal opportunities for every member of society, including people with disabilities, is an important principle of social justice and sustainable development. In recent years, Uzbekistan has been implementing a number of legislative measures aimed at protecting the rights of people with disabilities and their involvement in the workforce. In particular, article 42 of the Law "On the Rights of Persons with Disabilities" guarantees the equal right to work [1]. However, in practice, the level of participation of this category of the population in the labor market remains low. According to official data, in 2024, the employment rate among people with disabilities was only 8.5% [2], which is four times lower than among the rest of the working-age population. The reasons for this gap are related to deep social, economic and psychological factors.

The relevance of the problem. According to T.A.Mikhailova, graduates with disabilities are the most vulnerable category in the labor market. Lack of work experience, lack of adapted jobs, as well as the presence of stereotypes in society exacerbate the problem [3]. As a result, young people with disabilities are deprived of economic independence and are socially isolated. New Uzbekistan pays special attention to creating conditions for the active participation of all members of society, including people with disabilities, in economic activities. The International Labour Organization (ILO) estimates the economic losses from the exclusion of persons with disabilities from the labor market in the range of 3-7% of GDP [4].

Legal framework and existing mechanisms. The country has the following legal and economic mechanisms to support the employment of people with disabilities:

• tax benefits and subsidies for employers;
• introduction of quota jobs;
• vocational rehabilitation and retraining programs;
• a system of microcredit and compensation;

For example, if an employer creates an adapted workplace for an employee with a disability, he can receive a subsidy in the amount of 40 times the basic calculation index (BRP). In addition, 50% of the salary of the accepted employee is compensated for 6 months. However, in practice, only about 10% of employers are aware of such opportunities [5].

Disadvantages of the vocational education system. One of the key factors influencing the employment of graduates with disabilities is the level of their professional training. Since 2007, the list of professions recommended for people with disabilities has not been updated, which does not meet modern labor market requirements. As a result, many young people, having the potential to work, get jobs that are not in demand by the economy.

The need for social marketing. To increase the employment of people with disabilities, the social marketing approach is important, aimed at changing public attitudes towards people with disabilities, forming their positive image, stimulating employers and increasing the confidence of young people with disabilities in their abilities.

The main elements of a social marketing strategy include:

• information policy - the formation of a positive view of the labor potential of people with disabilities;
• awareness campaigns - familiarizing employers with the benefits of inclusive employment;
• motivational programs - stimulating the professional growth of youth with disabilities;
• cooperation platforms - creation of mechanisms for interaction between the state, Non-governmental non-profit organizations and the private sector;

Systemic problems. The analysis shows that the following systemic barriers remain when providing employment for young people with disabilities:

• outdated disability assessment system;
• ıınadequate workplace infrastructure;
• non-fulfillment of quotas by employers;
• psychological and social barriers;
• insufficient development of inclusive educational programs.

In our opinion, in order to eliminate these problems and increase the employment of people with disabilities at the state level, it is necessary to implement the reforms listed in table-1.

Table-1.

Key strategic directions for increasing employment [1]

Direction	Content
Reforming the system	Revision of the disability assessment system based on modern criteria.
Legal protection	Prevention of discrimination, raising public awareness about labor rights.
Modernization of education	Development and implementation of inclusive vocational training programs.
Cooperation with employers	Strengthening control over the implementation of quotas, expanding the promotion of tax benefits.
Infrastructure adaptation	Provision of physical and technical conditions at workplaces.
Development of social marketing	Creating a positive image of people with disabilities, changing public consciousness.

Conclusions and suggestions. Increasing the activity of graduates with disabilities in the labor market is the most important condition for ensuring the social stability of society. The following measures are proposed for this purpose:

- modernization of vocational education - development of adapted and digital educational programs for youth with disabilities;
- implementing a social marketing strategy - presenting disability not as a “problem”, but as an “opportunity for development”;
- stimulating employers by expanding the system of tax benefits, subsidies and bonuses;
- creation of a monitoring mechanism - strengthening control over the implementation of employment quotas;
- changing public consciousness is the active coverage of positive examples of employment of people with disabilities in the media.

As a result, the involvement of graduates with disabilities in the labor market not only contributes to their social integration, but also makes a significant contribution to the development of the country's human capital.

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[1]Author's development

MEDICAL SCIENCES

DISORDERS OF PSYCHOLOGICAL BEHAVIOR IN STUDENTS AND PSYCHOLOGICAL AND MEDICAL BIOLOGICAL METHODS OF ITS CORRECTION

Aliyev R.
5th year student
https://orcid.org/0009-0005-5536-6696
Tbilisi State Medical University
Tbilisi, Georgia
DOI: 10.5281/zenodo.18738450

Abstract

Psychological behavioral disorders in students (anxiety, depression, addictions, learned helplessness) are caused by stress, academic pressure, and social deprivation. Psychological and pedagogical methods (art therapy, behavioral therapy) and medical and biological approaches (regulation, physical therapy) are main methods used to improve mental health. Modernization in higher education makes mental health of a university student a fundamental chellenge for practical clinical psychology and medicine. In this context, the search for innovative conceptual approaches that ensure the effectiveness of interventions in this area is undoubtedly important. The use of appropriate systems of psychocorrectional and medical biological support for educational institutions, ensuring the stability of students' mental health, allows for increased effectiveness of the educational process and improved professional training for future specialists.

Keywords: Disorders, psychological, behavior, student, medical and biological, method, correction, regime, sleep, nutrition, sports, correction.

The development of innovative technologies in the organization of educational and training conditions for the educational environment and the identification of new forms of interaction between subjects of the educational process are necessary for a constructive solution to the problems of psychological and medical biological support for the mental health of students in higher education institutions, as well as the optimization of their psychological adaptation to the educational process. Mental health is a significant factor in students' psychological adaptation to the educational process, as well as their ability to cope with the emotional and stressful situations that arise during academic activities and exams at higher education institutions. Theoretical and empirical research in this area is scarce. It is crucial to recognize the critical role that mental health plays for students. Mental health is defined as a state of internal psychological well-being and the sufficiency of continuous mental activity, which is characterized by the determinism of mental phenomena, a harmonious relationship between the reflection of reality and the individual's attitude toward it, and adequate responses to the surrounding social, mental, and physical conditions of the individual's existence. It ensures faster and more effective psychological adaptation to the conditions of higher education. At this age, the transition from school to university education is a complex adaptive process, the nature of which significantly impacts mental health and the effectiveness of professional training. Furthermore, a high percentage of university students come from rural areas and move to the city for further education. This adds nuance to the adaptive processes and mental health. In such a situation, specialized psychological and medical biological support for students with various mental health needs should play a significant role. Such support will not only ensure the effectiveness of their psychological adaptation but also create constructive conditions for the further development of personal and professional self-awareness and the development of effective behavioral strategies in various life situations [2; 4].

Students' psychological health is a multifaceted concept, so it is necessary to identify its key components, which are most relevant to higher professional education. This issue is relevant due to the constantly changing demands on the Russian higher education system and its ultimate, ideal, "super-complex" product—a psychologically healthy young person. The knowledge, skills, and abilities students acquire during their university studies remain significant even in the modernization of the education system in our era. Nonetheless, the focus is on helping students acquire the skills and talents necessary to apply this information practically, including in the ever-changing contexts of life and the workplace. A proactive approach to life, a creative approach to solving professional problems, a need for self-knowledge, and a desire for self-realization not only in their profession but also in relationships with others—all these are indicators of psychological health. Therefore, we believe it is important to identify the key areas for maintaining and developing the psychological health of future specialists within the educational environment of a university [1;3].

Modern education should result in the development of competitive, socially responsible, proactive, and competent citizens, which is the foundation for the innovative development of the country's economy and society as a whole. This problem cannot be resolved without implementing student-centered and competency-based, psychological, and medical-biological approaches to student behavior modification, as well as changes in approaches to student adaptation to the university education system [2;4;6].

At this point in its development, psychology has enough knowledge about normal human psychological

development to comprehend not only what causes maladaptive students with abnormally high rates of behavioral inadequacy and neurotic personalities to emerge, but also—and perhaps most importantly—to create a set of psychoprophylactic and corrective measures for higher education institutions that could expedite and optimize students' adaptation processes.For example, incorporating various forms and methods of teaching voluntary and self-regulation techniques into psychology course curricula could be beneficial. This also applies to psychologically challenging situations in university student learning, such as public speaking and oral examinations. To prevent fatigue, monotony, boredom, and mental exhaustion in senior students, it is necessary to infuse the educational process with new forms and methods of teaching that enhance students' interest and energize their work [3;7;9].

Finding strategies to stop and rectify maladaptive processes, as well as researching students' lifestyle, academic achievement, and health, are just a few of the urgent problems that need prompt, thorough scientific analysis to maximize the nation's intellectual potential. One of the "diseases of civilization" is the issue of psychosomatic health, which has been the focus of extensive research for the past century. However, theoretical research has had little practical application. Paradoxically, most people know inexcusably little about their bodies, their structure and functions, or their health, including mental health, as a person's most valuable asset. Due to ignorance, people make many mistakes, sometimes fatal, that could easily be avoided. Human health primarily involves the maintenance and enhancement of both mental and physical qualities, as well as one's capacity to perform effectively[2;8;10]. A healthy lifestyle embodies a generalized and typical pattern of activities in student life, marked by purposeful self-organization, self-discipline, self-regulation, and self-development, all focused on fully realizing individual strengths, talents, and abilities. This lifestyle fosters a sociocultural environment that supports high levels of creativity, productivity, work and social engagement, along with psychological well-being. A healthy lifestyle fosters responsibility for one's own health [4;5].

According to experts conducting research in this area, three main groups of risk factors can be identified that pose a potential risk to students: psychophysical, social, and pedagogical. The following groups of risk factors are distinguished: medical and biological (health groups, hereditary factors, congenital characteristics, mental and physical developmental disorders); socioeconomic (large and single-parent families, teenage parents, unemployed families, families leading an immoral lifestyle; maladjustment to social life: running away, vagrancy, suicide attempts, aggressive behavior, alcohol and drug use); psychological (alienation from the social environment, self-rejection, neurotic reactions, impaired communication with others, emotional instability, failure in activities, failure in social adaptation, difficulties in communication, interaction with peers and teachers); pedagogical (inconsistency between the content of the educational institution's programs and the conditions of students' learning and their psychophysiological characteristics, the pace of mental development and the pace of learning, the predominance of negative assessments, lack of confidence in activities, lack of interest in learning, and inability to accept positive experiences) [5;9].

Actively addressing psychological behavioral problems in university students may also include such actions as significantly increasing daily fluid intake; improving nutrition; monitoring breathing; exercising and participating in competitive sports.

Mental self-regulation, which promotes the mobilization of psychophysiological capabilities, is also an active means of addressing these problems. Mental self-regulation is a specifically conducted mental activity aimed at correcting one's state. The main types of mental self-regulation include:

- relaxation, which is the conscious neuromuscular relaxation of the body, consisting of maximum contraction and relaxation of a specific area;

- autogenic training, based on the conscious suggestion of feelings of warmth, heaviness, and relief in various organs and areas of the body;

- meditation, which is a method of mental self-regulation using mental actions that help bring the human psyche into a state of deep concentration and self-immersion.

If the impact of psychological problems is significant, primary care measures should be taken:

– Avoid making important decisions unless lifesaving is at stake;

– Focus on your breathing (inhale slowly, hold your breath, and exhale slowly);

– Try to count to ten, and then continue workingIf the psychological stress occurs indoors, leave the room; wet your forehead and temples with cold water; drink a glass of water; look around; practice calming breathing; act calmly and carefully to avoid falling.

If the stress occurs outdoors, do the following: look around, mentally naming the surroundings; drink some water; practice calming breathing to relieve stress; take a light walk [6;10].

Given the diverse causes of student maladjustment, crisis prevention involves addressing two main, interconnected objectives. The first involves targeted interventions for individuals experiencing psychological crisis, addressing the borderline psychopathological disorders that often arise in this context.

This involves the use of various psychocorrectional and/or psychotherapeutic techniques, as well as differentiated psychopharmacotherapy. The second objective involves measures aimed at normalizing the individual's interpersonal relationships with those close to them and, if possible, eliminating the causes of conflict. This requires social interventions, which should involve the university administration and community organizations. Only through such a multifaceted approach can one achieve full rehabilitation in a crisis situation. The primary role in preventing student maladjustment belongs to medical, psychological, and social support offices located in student health centers or university outpatient clinics. Qualified specialists in borderline psychopathology (psychologists, psychotherapists, psychiatrists) provide consultations. Medical and psychological assistance can be obtained anonymously.

If indicated, staff can refer students to a crisis inpatient unit. The work of these offices includes identifying the initial stages of maladjustment, as well as timely prevention and providing medical and social-psychological assistance to rehabilitate students. From the very beginning of training, it is advisable to conduct screening to determine the degree of socialization and adaptation of the individual. Individuals with various forms of deviant behavior, past or present, should be included in a monitoring group, which is subject to dynamic monitoring throughout the course of further training, especially during exam periods [3;6;8].

Psychopharmacotherapy is used for anxiety and depression, as well as for the treatment of severe psychological and behavioral disorders in students. Concurrent psychotherapy is necessary, the strategic goals of which depend on the type of behavioral disturbance, personality characteristics, and clinical structure of the mental disorders. Medical and psychological care for psychological behavioral disorders should be comprehensive, implemented within the framework of a biopsychosocial model of the development of these disorders, and utilized modern psychotechnologies such as neurolinguistic programming, Ericksonian hypnosis, and Gestalt therapy. Furthermore, in some cases, the method of epistemological metaphor was employed.

In conditions of psychological overload, intense mental work, time pressure, and limited physical activity (perhaps due to reluctance or simply laziness), physical education and sports undoubtedly take on a preventative role among students, serving as a means of rehabilitation and restoring an optimal (for a young person) psychophysiological state. Understanding your body, learning to stimulate its activity, and relieving neuromuscular tension and psychoemotional fatigue-this is the goal of restoring a student's physical and psychological well-being. I would like to quote the ancient wisdom: "He who controls himself is the strongest!" Therefore, this briefly described restorative (rehabilitative) method is quite accessible to everyone.

Conclusion:

Psychological intervention for behavioral disorders in students focuses on developing self-regulation, stress reduction, and adaptation, using cognitive behavioral therapy, art therapy, personal growth training, and breathing techniques. The primary focus is on overcoming academic failure, addressing emotional breakdowns, and developing productive behavior skills. Medical and biological methods for student behavior modification are aimed at optimizing the psychophysiological state, increasing adaptation to mental stress, and preventing stress. The main approaches include physical exercise, breathing exercises, rationalizing the daily routine, spa treatment, and, if necessary, pharmacological support, aimed at improving health and behavior. To address these issues, students are advised to undergo autogenic training, sometimes called psychomuscular training, as it helps relieve neuromuscular tension associated with the restructuring of nervous system regulation. As a rule, autogenic training, or autogenic training, has no contraindications for otherwise healthy individuals. The exceptions are acute mental illnesses and decreased intelligence.

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PEDAGOGICAL SCIENCES

METHODOLOGY FOR SOLVING STEREOMETRIC PROBLEMS: A SYSTEMATIC APPROACH TO SPATIAL THINKING

Aliyev S.
Department of Higher Mathematics and Methodology of Teaching Mathematics, Faculty of Mechanics and Mathematics, Baku State University, Baku, Azerbaijan
Allahverdiyeva N.
Department of Mathematics and Informatics Teaching Technology, Faculty of Mathematics, Sumgait State University, Sumgait, Azerbaijan
Yuzbashiyeva N.
Department of Higher Mathematics and Methodology of Teaching Mathematics, Faculty of Mechanics and Mathematics, Baku State University, Baku, Azerbaijan
DOI: 10.5281/zenodo.18738470

Abstract
This article proposes a comprehensive, step-by-step methodology designed to demystify the process of solving stereometric problems and address the prevalent difficulties in spatial geometry education. The framework is built on two foundational pillars: (1) a rigorous command of theoretical principles coupled with techniques for accurate spatial visualization, and (2) a universal, six-step problem-solving algorithm. This algorithm guides students from initial problem comprehension and diagram construction through the critical stages of spatial deconstruction—identifying key configurations and reducing three-dimensional complexities to manageable two-dimensional planimetric facts. The methodology explicitly integrates multiple solution strategies, including classical geometric reasoning, the coordinate-vector method, and geometric transformations, empowering learners to select the most efficient tool. By fostering a structured approach to spatial analysis, this framework aims to systematically enhance students' logical reasoning, spatial imagination, and self-efficacy, ultimately making stereometry a more accessible and intellectually engaging domain.
Keywords: Stereometry, spatial thinking, problem-solving methodology, geometry education, spatial visualization, secondary school mathematics.

Introduction. Stereometry, the branch of geometry dedicated to the properties of figures in three-dimensional space, is widely recognized as one of the most demanding topics within the secondary school mathematics curriculum. The challenges students encounter are profound and multifaceted, rooted not only in the necessity to assimilate a complex body of theoretical knowledge—including axioms, spatial relationships, and the properties of polyhedra and solids of revolution—but also, and more critically, in the requirement for a well-developed spatial imagination. This cognitive ability to visualize, manipulate, and reason about forms in space is fundamental to accurately depicting three-dimensional configurations on a plane, identifying key geometric relationships, and effectively reducing spatial problems to solvable two-dimensional facts. Without a structured approach to cultivate these skills, stereometry can remain an abstract and inaccessible subject, leading to student frustration and disengagement.

Enhancing the quality of mathematics education, particularly in challenging domains like stereometry, necessitates a commitment to diversifying pedagogical strategies and refining methodological approaches. A significant body of research has explored various techniques for improving geometric understanding and problem-solving proficiency, encompassing studies on classical methodologies, alternative solution paths, the pedagogical structuring of content, and the transformative potential of Information and Communication Technologies (ICT) [1-16].

This article seeks to synthesize and build upon these strands of research by proposing a comprehensive, systematic methodology for solving stereometric problems. The core premise of our approach is that success in stereometry can be demystified through a structured sequence of cognitive and procedural steps. We advocate for a strategy that begins with a solid command of theory and principles of effective visualization, proceeds through a disciplined process of problem analysis and decomposition into planar components, and culminates in the strategic selection and application of an appropriate solution method—be it classical planimetric reasoning, the coordinate-vector approach, or the use of geometric transformations. By integrating rigorous theoretical grounding with practical heuristics and acknowledging the supportive role of technological tools, this framework aims to develop students' logical reasoning, spatial intuition, and overall problem-solving confidence.

1. Foundation: Theory and Visualization

The mastery of stereometry begins with a solid grasp of its theoretical underpinnings and the ability to visualize spatial relationships accurately. This foundational stage is critical because it provides the logical framework and the mental tools necessary to deconstruct and solve three-dimensional problems. Without a firm theoretical understanding, students may struggle to identify relevant principles; without proficient visualization, they may misinterpret spatial configurations.

1.1. Theoretical Pillars of Stereometry

The theoretical foundation encompasses several core areas:

Axioms of Stereometry and Their Corollaries: These are the self-evident truths that form the basis of all proofs in spatial geometry. Understanding axioms such as "through any three non-collinear points there exists exactly one plane" and their immediate consequences allows students to construct logical arguments about the existence and uniqueness of geometric elements (e.g., lines of intersection, parallel planes).

Relative Positions of Lines and Planes in Space: Students must thoroughly comprehend the definitions and conditions for:

Parallelism: Between lines, between a line and a plane, and between planes. Recognizing parallel structures often simplifies problems by allowing the transfer of angles and ratios.

Perpendicularity: Including the crucial theorem stating that a line is perpendicular to a plane if it is perpendicular to two intersecting lines in that plane. This is fundamental for distance and angle calculations.

Skew Lines: Lines that are neither parallel nor intersecting. Understanding the concept of the common perpendicular and the distance between skew lines is essential for more advanced problems.

Properties of Key Spatial Figures: A detailed knowledge of definitions, elements, and specific properties is required for:

Polyhedra: Prisms (right, oblique), pyramids (regular, irregular), parallelepipeds (rectangular, oblique). Key properties include lateral edges, altitudes, apothems, and diagonal sections.

Solids of Revolution: Cylinders, cones, and spheres. Important concepts involve generators, axes, and cross-sections (e.g., circular, parabolic).

*Formulas for Surface Areas and Volumes***:** Memorization should be accompanied by an understanding of the derivation and interconnection of these formulas. For instance, recognizing that the volume of a pyramid is one-third of the corresponding prism's volume can aid in problem-solving.

1.2.Principles of Accurate Spatial Depiction

The ability to create clear and informative drawings is not merely artistic but analytical. A well-executed drawing serves as a laboratory where spatial relationships can be explored and tested.

Conventions for Clarity: Adhering to standard conventions avoids ambiguity.

— Depict parallel lines as parallel in the drawing to preserve this relationship visually.

— Use dashed lines to represent edges or contours that are hidden from view, which is vital for understanding the full three-dimensional structure.

— Employ the properties of parallel projection consistently. For example, the midpoints of segments project to midpoints, and ratios along a line are preserved. This allows planar geometry facts to be applied to the projection.

Strategic Viewpoint Selection: The choice of perspective can dramatically simplify a problem.

— Representing a plane as a parallelogram is conventional and effective.

— For complex figures like pyramids or truncated cones, choosing a viewpoint that clearly shows the base, altitude, and any relevant sections (especially those perpendicular to the base) is crucial. Sometimes, multiple complementary drawings (e.g., a frontal view and a top view) are beneficial.

From Visualization to Analysis: The drawing should actively support the problem-solving process. It is on this drawing that students will:

— Label all vertices systematically (e.g., A, B, C, ... for the base; A_1, B_1, C_1, ... for a parallel upper base).

— Mark all given data (lengths, angles, ratios) directly on the figure.

— Construct auxiliary elements (heights, projections, sections, linear angles of dihedral angles) as dictated by the problem's logic.

This foundational combination of theory and visualization equips the learner with the necessary "vocabulary" and "grammar" to read and interpret stereometric "sentences." The following section presents the step-by-step "syntax" for solving these problems, building directly upon the skills established here.

2. Algorithm for Solving a Stereometric Problem: A Step-by-Step Strategy

The solution to any stereometric problem, regardless of its apparent complexity, can be reliably reached by following a disciplined, sequential strategy. This universal algorithm transforms a daunting spatial challenge into a manageable series of logical operations. Its purpose is to provide a clear roadmap, preventing the student from feeling lost and ensuring no critical aspect of the problem is overlooked. The following six-step sequence is designed to be internalized through practice until it becomes an automatic problem-solving reflex.

Step 1: Careful Reading of the Condition and Constructing a Drawing. This initial step is arguably the most important, as a misunderstanding here propagates through the entire solution. It requires slow, deliberate engagement with the text. The solver must meticulously extract all given data: numerical values of lengths, measures of angles, ratios of segments or volumes, and qualitative relationships (e.g., "the pyramid is regular," "the line is perpendicular to the base"). Every piece of information is a clue. Immediately after, a drawing must be constructed—not a sketch, but a reasoned geometric representation. This drawing is the primary workspace. It must be drawn according to the condition, respecting given proportions and relationships as much as possible. If the problem involves an angle between a line and a plane, the perpendicular projection of the line onto the plane must be shown, and the linear angle must be clearly indicated. For a dihedral angle, its linear angle, constructed on the edge and perpendicular to it, must be drawn. All vertices should be labeled with letters (e.g., ABC for a base, S for a pyramid's apex), and all known lengths, angles, and right-angle symbols must be marked directly on the figure. A clean, well-labeled drawing often suggests the next step.

Step 2: Analysis of the Condition and Choice of Solution Method. With the drawing as a visual aid, the solver must now classify the problem's ultimate goal. This analysis dictates the general solution path. Problems generally fall into three categories: *Proof problems*, which require establishing a geometric fact (e.g., proving two lines are parallel or that a point lies on a

specific plane); *Calculation problems*, which ask for a numerical result (a distance, angle, area, or volume); and *Combined problems*, which first require a proof to unlock a necessary element for a subsequent calculation (e.g., proving two lines are perpendicular to then use that right triangle in a Pythagorean calculation). Identifying the type early prevents wasted effort and helps select the appropriate toolkit.

Step 3: Identifying the Key Spatial Configuration. This is the core of spatial thinking: the ability to mentally dissect a three-dimensional figure to reveal simpler, solvable two-dimensional components within it. A complex spatial problem almost always simplifies into one or more planar problems. The solver must learn to "see" these embedded configurations. Common strategies include identifying meaningful *sections* (e.g., a diagonal section of a prism that forms a rectangle or triangle containing key elements), constructing *orthogonal projections* (especially to find distances from points to lines or planes, or angles between lines and planes, which invariably involve right triangles), and introducing *auxiliary planes*. An auxiliary plane is a powerful tool; by constructing a new plane that contains certain scattered points or lines, the solver can bring them into a single, manageable two-dimensional context where standard planimetric theorems apply.

Step 4: Application of Planimetric Facts. Once the key planar configuration (most often a triangle) is isolated, the problem temporarily ceases to be stereometric. At this stage, the solver applies the full arsenal of planimetry—the geometry of the plane. This typically involves solving triangles using the Law of Sines and the Law of Cosines, identifying and utilizing similar or congruent triangles to establish proportional relationships, applying the Pythagorean Theorem in right triangles, and calculating areas using various formulas (base-height, trigonometric, or Heron's formula). The properties of similar figures, where the ratio of linear dimensions, areas, and volumes follows a known scale factor, are also frequently indispensable. Mastery of planimetry is non-negotiable for success in stereometry.

Step 5: Choosing a Method for Calculating the Desired Quantity. For calculation problems, flexibility is key. Several powerful methods exist, and the choice depends on the specific configuration and the given data. *The Volume Method* is elegant for finding distances from points to planes, especially in pyramidal structures. By calculating the volume of a tetrahedron or pyramid in two different ways (using different bases), one can set up an equation to solve for the altitude, which is the desired distance. *The Coordinate-Vector Method* is the most universal algebraic approach. It involves imposing a convenient rectangular coordinate system onto the figure, assigning coordinates to all key points, and then using vector algebra formulas to compute distances, angles, and equations of planes. Its great advantage is that it reduces the need for complex spatial insight to procedural calculation, though it can be computationally heavy. *The Method of Geometric Transformations* (parallel translation, rotation, symmetry) is useful for repositioning elements to more favorable locations, for example, translating a segment to bring its endpoint to a more convenient plane, or using symmetry to find the shortest path on a polyhedron's surface.

Step 6: Verification of the Result. The final step is a sanity check to guard against logical or arithmetic errors. The solver should assess the *plausibility* of the answer: a distance or volume cannot be negative; an angle in a triangle must be less than 180 degrees; in a right triangle, the hypotenuse must be the longest side. Checking *special or degenerate cases* can also be insightful. Furthermore, if time permits, solving the problem using a *different method* provides the strongest verification. This step cultivates a critical mindset and reinforces the interconnectedness of different geometric approaches, solidifying the learner's understanding. By diligently following this six-step algorithm, students build a reliable framework that turns stereometric problem-solving from an intimidating task into a structured and conquerable process.

3. The Method of Geometric Transformations.

In addition to direct calculation and algebraic approaches, the method of geometric transformations offers a powerful and often elegant strategy for simplifying stereometric problems. This approach involves mentally or graphically moving geometric figures within space while preserving their essential properties, thereby repositioning them into more advantageous configurations where relationships become clearer or calculations more straightforward. Mastering these transformations enhances spatial reasoning and provides flexible tools for tackling otherwise cumbersome problems.

Parallel Translation involves shifting a line, segment, or plane in space such that it remains parallel to its original position. This transformation is particularly useful when elements of a problem are inconveniently positioned, making it difficult to perceive relationships or construct necessary planar figures. For example, when two skew lines are given, translating one along a direction parallel to itself can bring it into a position where it lies in the same plane as the other, allowing the angle or distance between them to be analyzed in a single, workable plane. Translation preserves lengths, angles, and parallelism, enabling the solver to reconfigure a spatial layout without altering any metric properties.

Rotation is employed to revolve a figure around a specific axis, either in space or within a plane. Its most prominent application in stereometry lies in constructing *developments* (nets) of polyhedral surfaces, where rotating faces around their common edges into a single plane allows for the direct measurement of shortest paths—so-called “geodesic” distances across the surface. In spatial reasoning, a well-chosen rotation can align a figure with coordinate axes or reposition it so that hidden symmetries become apparent. For instance, rotating a pyramid so that its base lies in a horizontal plane often simplifies the drawing and clarifies the true lengths of lateral edges and altitudes.

Symmetry leverages the inherent reflective properties of certain geometric configurations. Problems involving distances between points, lines, or planes can frequently be simplified by reflecting one element across a plane or line of symmetry. The classic example

is finding the shortest path from a point to another via a line or plane: by reflecting one point across the mirror, the problem reduces to finding the straight-line distance between the reflected point and the other original point, as this path's reflection corresponds to the actual shortest route in the original space. Recognizing and utilizing planes of symmetry in regular polyhedra, cylinders, or cones can also halve the complexity of a problem by allowing the solver to focus on one symmetric half.

Conclusion. In conclusion, proficiency in stereometry is not an innate talent but a skill that can be cultivated through a structured and strategic approach. The methodology presented in this article—progressing from foundational theory and disciplined visualization to a systematic six-step algorithm—provides learners with a reliable cognitive scaffold for deconstructing and solving spatial problems. Its core strength lies in teaching how to *think* in three dimensions by strategically reducing complexity to solvable planimetric facts and offering a versatile toolkit of solution methods. We argue that the synergistic mastery of both synthetic-geometric and algebraic-coordinate techniques, complemented by transformational reasoning, equips students with adaptable problem-solving intelligence. Ultimately, consistent application of this framework does more than yield correct answers; it builds spatial intuition, reinforces logical reasoning, and fosters metacognitive awareness of one's own problem-solving process. By transforming an opaque challenge into a clear sequence of operations, this methodology can help shift students' perception of stereometry from a daunting obstacle to a structured and rewarding intellectual pursuit. Future work could focus on empirically validating the effectiveness of this approach in diverse classroom settings and exploring its integration with interactive digital modeling tools.

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PHILOLOGICAL SCIENCES

THE CRUCIAL ROLE OF MENTAL MAPPING FOR REINFORCING COGNITIVE AND METACOGNITIVE PROCESSES ON READING COMPREHENSION

Hovakimyan E.
M.Nalbandyan State University of Shirak
Hovhannisyan A.
D. Sc, Prof., M. Nalbandyan State University of Shirak
The research is performed in the frame of the the thesis covering the following topic "The Proficiency of Cognitive and Metacognitive Strategies for Developing Learner's Reading Skills"
DOI: 10.5281/zenodo.18738481

Abstract
It's a well- acknowledged fact, that among the four key skills for language learning (listening, speaking, reading, writing) reading plays a special role. Reading ability goes beyond the strictly linguistic plane and takes in a process of text interpretation, from decoding and linguistic comprehension to evaluation. Both cognitive and metacognitive strategies go hand in hand to provide successful comprehension, the former helps students to construct meaning while the latter guides, regulates and evaluates. The paper reports research findings of teaching reading through mental mapping, embracing cognitive and metacognitive strategies. Adopting the mind-mapping method our study examines how student's schemata affect the usage of cognitive and metacognitive strategies while teaching reading intermediate level university students. The mind mapping makes the students recall their prior knowledge and use it in the process of reading. Each student's mental map is unique, shaped by prior experiences, motivations, and subjective feelings, resulting in successful navigation in both familiar and unfamiliar texts.
Keywords: reading comprehension, cognition, metacognition, schema theory, memory, mental mapping,

1. Introduction

While dealing with written discourse, readers are often unaware of the cognitive complexity involved in reading process. It involves more than basic interpretation of written discourse and surpasses the simple decoding of words to involve constructing meaning from text, integrating prior knowledge, and applying various *cognitive and metacognitive strategies.* Readers do not merely draw on information from the text but for its interpretation, they also contribute to their own experience and prior knowledge. Research on reading is a multidisciplinary process as it involves psychology, linguistics and education. *This makes reading one of the key skills to be taught to English as second language (ESL) students.*

Reading is a dynamic process that cannot be taught as such. However, depending principally on the learner's ability to learn, it might be facilitated by helping the learners acquire specific strategies that aid their efforts to understand the texts. As Azizifar et al. note "the teaching of reading requires the application of various types of strategies, such as tapping previous knowledge, questions, and making predictions, constructing gist, monitoring, revising meaning, reflecting and relating" (2015, p. 192) which supports an argument that understanding and practicing strategies to interact and engage with the text is necessary for students to become good readers.

2. Cognitive and Metacognitive Learning Strategies in Reading Comprehension

Cognitive strategies are learner- centered approach going beyond linguistic plane and dealing with perceptive, attitudal, sociological factors. Cognitive strategies facilitate the reader's understanding of written discourse as good readers try to determine the unfamiliar words and concepts before and while reading to begin interpreting text more successfully.

Grabe (1991, p. 379) highlights six general component skills that are used by good readers:

1. *Automatic recognition skills*- a virtually unconscious ability, ideally requiring little mental processing to recognize text, especially for word identification.
2. *Vocabulary and structural knowledge*- a sound understanding of language structure and a large recognition vocabulary.
3. *Formal discourse structure knowledge*- an understanding of how texts are organized and how information is put together into various genres of text (e.g., a report, a letter, a narrative)
4. *Content/word background knowledge* – prior knowledge of text related information and a shared understanding of the cultural information involved in text.
5. *Synthesis and evaluation skills/ strategies*- the ability to read and compare information from multiple sources, to think critically about what one reads, and to decide what information is relevant or useful for one's purpose.
6. *Metacognitive knowledge and skills monitoring*- an awareness of one's mental processes and the ability to reflect on what one is doing and strategies one is employing while reading.

R. Oxford (1990) stated that there are two kinds of learning strategies; direct strategies and indirect strategies. Direct strategies consist of memory strategies, cognitive strategies, and compensation strategies. Meanwhile, indirect strategies consist of metacognitive strategies, affective strategies, and social strategies. While all of these strategies play an important role in language learning, the present article focuses particularly on cognitive and metacognitive strategies, given their central role in reading comprehension.

Reading is a *cognitively complex* process involving coordination of multiple mental functions. It is influenced by attentional control, perception, working memory, and prior knowledge. By using cognitive reading strategies, readers can process information in texts more effectively and understand the author's message. These strategies include making predictions, asking questions, summarizing information, making inferences, visualizing, and answering questions. These strategies help readers obtain, store, and use information from reading more efficiently.

As McNamara (2009) points out, reading strategies are essential to successful comprehension because readers can overcome reading problems in order to become better readers. In other words, *cognitive strategies facilitate the reader's understanding of the information because good readers try to determine the meaning of unfamiliar words and concepts in the text before and while reading in order to begin interpreting information in a text more successfully.*

Skimming strategies

Richards et al. (1992) discovered that the skimming strategy is one of the reading strategies, and it is used when the Wants to get the main idea of ideas from a passage. Skimming is essential for comprehending the general meaning of a passage, comprehending how the passage is structured, the structure of the text, and understanding the writer's intentions. The reader must organize the information and retain some of it because it is not enough to locate it. It is also a writing tool. According to the researcher, *skimming strategies are utilized by readers to obtain a general idea about the content of printed materials by scanning the text.*

Guessing meaning from the text

Contextual guessing is one amongst the foremost important strategies that build learners‟ vocabulary, and increase their reading comprehension. Bialystok (1983, 2001) stated that this strategy could be used as a compensation one for first and second language reading comprehension, because while reading an overseas text, EFL learners are expected to face *unknown words in the context they are dealing with, they fight to collect information from the encompassing words to urge a general understanding of its meaning*.

Scanning strategies

F. Great (1981) argued that the scanning strategy is a reading technique that utilizes readers to find *specific information without reading the entire text by first looking in at the title, table of contents, and so on*. The researcher believes that the scanning strategy is a type of reading strategy and that it is used to locate specific information. (Md. Harun Rashid, Wang Hui, Jahirul Islam, 2021)

Predicting strategies

Prediction strategy is related to what is expected to happen again in the text. It is achieved by successful readers who mean: they used diagrams, headings, and text and personal knowledge to shape projections before starting to read. (Md. Harun Rashid, Wang Hui, Jahirul Islam, 2021)

Summarization strategy

The summarization technique is one of the reading techniques, *and it is a method of restarting the original text's context with one's own words*. The findings are usually relatively short and contain the critical point, which summarizes the text succinctly. It is sufficient for stages of high education. This approach includes summarizing the remaining content in a succinct description by consistently extracting unimportant material. Thus, in other words, it is the only tactic readers have left. The details or the fundamental concepts of a given text must be arranged or preserved using the reader’s type. (Md. Harun Rashid, Wang Hui, Jahirul Islam, 2021)

Visualizing

Studies have shown that students who visualize while reading have better recall than those who do not (Pressley, 1977). *Readers can take advantage of illustrations that are embedded in the text or create their own mental images or drawings when reading text without illustrations.*

Questioning

Asking and answering questions about text is another strategy that helps students focus on the meaning of text. Teachers can help by modeling both the process of asking good questions and strategies for finding the answers in the text.

Learners “construct knowledge” using cognitive strategies, and they guide, regulate, and evaluate their learning using metacognitive strategies. It is through this “thinking about thinking,” this use of metacognitive strategies, that real learning occurs. As students become more skilled at using metacognitive strategies, they gain confidence and become more independent as learners.

Metacognition refers to the knowledge and control that we have over our cognitive processes. On a general level, metacognition includes awareness and control of planning, monitoring, repairing, revising, summarizing, and evaluating. *Essentially, we learn awareness of our comprehension processing.* More specifically, we learn strategies that support our comprehension (our awareness of strategies) and we learn how to carry out these strategies effectively (our control of strategies) (Baker, 2002, 2008; Pressley, 2002). One reason why metacognition is significant is that if learners are not aware of when comprehension is breaking down and what they can do about it, strategies introduced by the teacher will fail. As O’Malley et al. have pointed out: “students without metacognitive approaches are essentially learners without direction or opportunity to review their progress, accomplishments, and future directions” (1985, p. 561).

If cognitive reading strategies are about knowing what strategy to use and how to apply it, then metacognitive strategic knowledge involves understanding the rationale for applying a particular strategy in a particular context, and evaluating its usefulness in terms of appropriacy and effectiveness for that context. Auerbach and Paxton (1997) argue that strategic reading can only become efficient when metacognitive strategies, such as working towards a particular goal while reading, are actively used.

Proficient readers use one or more metacognitive strategies to comprehend texts. There are three main as-

pects of metacognition: metacognitive knowledge, metacognitive monitoring, self-regulation and control (Pintrich, Wolters and Baxter, 2000). The first group consists of cognitive learning strategies which the learner uses to regulate the process of knowledge acquisition. These include, for example, elaboration strategies such as the building of links to prior knowledge, or memory strategies such as note taking. The second group consists of metacognitive control strategies. Central here are activities like the planning and monitoring of learning activities, the evaluation of learning outcomes and the adaptation to varying task demands and (unexpected) difficulties, for example, an increase in directed efforts. In addition to these two groups, which are dominant in research and crucial for the learning process, a third group of strategies in the model developed by Pintrich and Garcia (1994) is dedicated to resource management. These strategies are concerned with the control of the general conditions associated with learning, for example, time management and management of the learning environment

According to Carrell, Gajdusek and Wise (1998), examples of specific metacognitive strategies in reading may include: a) establishing objectives in reading, b) evaluating reading materials, c) repairing miscomprehension, d) evaluating the ongoing understanding of the text, e) analyzing the text and paragraph structure to clarify the author's intention, f) adjusting reading speed and selective cognitive strategies accordingly, and g) engaging in self-questioning to determine if the objectives have been reached. Thus, reading is a metacognitive, as well as a cognitive process. While cognitive strategies refer to deliberate actions that readers take in their efforts to understand texts, metacognitive strategies emphasize the monitoring and regulative mechanisms that readers consciously use to enhance comprehension.

Studies demonstrate that successful comprehension does not occur automatically. Rather, it depends on directed cognitive effort, referred to as metacognitive processing, which consists of knowledge about and regulation of cognitive processing. During reading, metacognitive processing is expressed through strategies, which are "procedural, purposeful, effortful, willful, essential, and facilitative in nature". "The reader must purposefully or intentionally or willfully invoke strategies" (Alexander & Jetton 2000, p. 295), and does so to regulate and enhance learning from text. Through metacognitive strategies, a reader allocates significant attention to controlling, monitoring, and evaluating the reading process (Pressley 2000; Pressley, Brown, El-Dinary, & Afflerbach 1995).

Poor readers are less aware of effective strategies and of the counterproductive effects of poor strategies, and are less effective in their monitoring activities during reading. Adult and college readers who show evidence of metacognitive deficiencies may be the most aware and capable of monitoring their mental processes while reading.

1. Planning

Researchers like Brown and Palincsar (1982) and Zimmerman and Pons (1986) explained that learning needs the capability of planning for learning strategies. Reading is a three-step pre-reading, reading, and post-reading practice. Zimmerman (2008) described that the objective setting is a procedure to be utilized as a part of the planning stage by calling attention to that while setting testing objectives incite the accomplishment of larger amount execution, setting troublesome objectives is not typically regarded valuable in controlling learners' regulation in Therriault case of objectives may not seem reachable particularly.

2. Monitoring as Metacognitive strategy

Thiede, Anderson, and Therriault (2003) believed that reading and comprehension need to monitor learners' understanding during reading accurately. Self-regulated behavior in reading can be identified through monitoring the text when it is comprehended by the readers. Thiede, Anderson, and Therriault (2003) further asserted that self-regulated learning models help readers to read the text through "learning for the to-be-learned material" philosophy that needs to form a wish to follow for better comprehension. In this strategy, learners do monitor in order to see in what way material is taken for comprehension. Monitoring is used to evaluate the level of readers. If the level of learning is achieved, the readers do leave more learning. If the desired of learning of the readers is not yet achieved, the readers continue reading till its success (Thiede, Anderson, & Therriault, 2003). They further states that there is a need of accuracy in monitoring comprehension of students in order to make them independent learners. Independent or self- regulated readers take responsibility of their own reading and monitor their comprehension level. Most readers reread material in order to answer close reading questions. Schiff and Calif (2004) stated that monitoring in reading is implemented for checking intertextual features that include stylistic features, complex sentence features, and markers in order to integrate novel material for reading comprehension. There are other metacognitive strategies including think-aloud, self-questioning, and self-regulating associated for monitoring of learners' reading and comprehension.

3. Think-Aloud Strategy

Newell and Simon (1972) developed this strategy for evaluation comprehension of the students. Block (1986) called this strategy as problem solving for readers to read and comprehend well by participating in reading actively. Think aloud supports readers to learn through this cognitive strategy related to metacognitive strategies to help students for better performance through thinking and comprehending the text. According to Rosenshine and Meister think-aloud is a scaffolding device for imparting cognitive strategies to make sure of its modeling in comprehension by articulating students' thoughts and their reading loudly to be heard by all peers in class. Rosenshine and Meister (1992) asserted that while learners do practice by questioning through reading task; they are given support by their teachers who model their thinking practices aloud by allowing them to verbalize in the presence of class. Block (1986) considered think-aloud as a strategy to observe the material directly for better reading practices. Anderson (1991) illustrated think- aloud practices

that students employ this cognitive strategy for summarizing and clarifying difficult material in the class.

4. Questioning Strategy

Questioning Strategy is used to support students to evaluate their comprehension, to find alternatives, and to raise promising generalities when applying their knowledge freshly learned in class. Benchmarkeducaton (2011) stated that expert students are trained to question in terms of the content of material and elaborate their knowledge accordingly. Similarly, Collins and Smith (1982) explained that questioning strategy is used to correct misunderstandings in the reading of the text and in comprehension. However, Livingston (2003) observed that questioning strategy in reading is used to select cognitive knowledge for monitoring the metacognitive activity of reading and comprehension. Rawson, O'Neil, and Dunlosky (2011) suggested

5. Self-analysis having twofold advantages that include:

1) It develops monitoring accuracy of students resulting effectively by controlling the learning and comprehension of the readers.

2) It improves recollection method for collecting or retaining previous concepts learned by readers to be used at the time of need correctly.

6. Self-Regulating Strategy

This approach denotes the capability of students to control their learning of reading and comprehension.

According to Zimmerman and Pons (1986) Self-Regulating strategy involves actions directed towards certain goals of the students in order to obtain new knowledge in terms of better comprehension. Further, Gall, Gall, and Borg (2010) observed cognitive strategies and informed that these strategies develop text reading behavior of students and make them self-regulatory for using problem solving methods, self-evaluation, and self- control in learning. Similarly, Brown and Palincsar (1984) proposed two level of reading that includes:

1) Students read fast without any efforts without trying for comprehension the text.

2) Students read slowly and laboriously for better reading by monitoring the whole activity for excelling their comprehension.

However, Chapman (1993) suggested that active readers read slowly with great attention by applying different approaches of cognitive strategies in order to comprehend the material; this depends on individual dissimilarities in reading based on monitoring level.

7. Evaluating as Metacognitive Strategy

Evaluating plays a vital role in reading for several purposes. In a few words it is an art of judging the text for specific meaning to be utilized for certain objectives. L. Oczkus (2004) proposed five important factors of evaluation in reading and comprehending material to determine readers with possibility of power in:

1) The importance attained from written manuscript

2) Accuracy in reading and credibility in comprehension

3) Appropriate material

4) Personal attachment with text for enjoyment

5) Self progress in reading

3. Method and Procedures

For the purpose of integrating cognitive and metacognitive strategies in teaching Reading in EFL class, we adopted a mixed-methods. The quasi-experimental nature of the study is conditioned by the fact that random assignment of participants was not feasible due to institutional and cultural constraints. The research focuses on examining pedagogical impact of strategy-based reading instructions on ESL students' reading comprehension and metacognitive awareness.

For the purpose of integrating cognitive and metacognitive strategies in teaching via using classroom-based approach with elements of quasi-experimental method and method of mental – mapping or cognitive-mapping.

Mental- mapping method emerged from interdisciplinary research in psychology, geography, and anthropology, highlighting the connection between perception and behavior. As T. Buzan states, mental-mapping is all about the peculiarities of our thinking, since it is not organized linearly, but has a branching structure, each concept in our head is connected with other concepts, these and other concepts are connected with third ones, and so on.(2007)

Using the map, you can delve deeper into the text you are reading, focus on important details, see semantic images, and come up with a topic and idea. It is a technology for displaying information graphically; a tool that allows you to effectively structure information and think using your full creative potential.

The instructional intervention was implemented within a naturally occurring setting during a teaching internship and followed a structured pre-reading, while-reading, and post-reading model. This design allowed the observation of changes in students' reading behavior and written performance over the course of instruction.

Participants of the study

Participants of the study were 11 BA second year students at the English Department in M. Nalbandyan State University of Shirak, during the first semester of 2025/2026 studying a three-credit hour course entitled "English language written and oral language" involving component "Home reading" an 80 minutes meeting once a week session. All students have studied English as a foreign language during the school year from grade 3 to grade twelve.

Instructional Material

Somerset Maugham's short story "The Happy Man" was chosen as an instructional material. The text was chosen for its thematic depth, manageable length, inference-making and discussion in an EFL classroom. The short text associated with short stories motivates students with a basic knowledge of English because it is easier for them to form associations, infer meanings and notice an improvement in reading comprehension. Additionally, short stories are a meaningful resource that enhances critical thinking, reflection and comprehension of new words and expressions in a second language.

Instruments

To collect data on students' reading strategies and metacognitive awareness, a self-report questionnaire

was developed and administered in connection with the reading of W. Somerset Maugham's The Happy Man. The questionnaire consisted of both closed-ended and open-ended items. Closed-ended items were rated on a five-point Likert scale and focused on the use of cognitive and metacognitive reading strategies, while open-ended questions encouraged reflection on comprehension, strategy use, and personal response to the text. Although self-report instruments rely on learners' subjective perceptions, they are widely used in reading research to assess strategy awareness and metacognitive processes, which are not directly observable during reading.

In addition to questionaries mental maps, which was used as qualitative source of data. Mental maps served both as a learning tool and as an indicator of cognitive organization and metacognitive awareness, as students were required to select, structure, and hierarchize information from the story.

Techniques

The instructional intervention was organized according to a three-stage reading model: pre-reading, while-reading, and post-reading. At the pre-reading stage, students were provided with background information about Somerset Maugham, historical, literal, and cultural context in "The Happy Man", and thematic focus of the texts. Cognitive strategies such as prediction and introductory discussions were used to activate prior knowledge and support metacognitive planning.

During the while-reading stage, students engaged in guided reading activities aimed at fostering cognitive strategies such as skimming, scanning, guessing meaning from context, summarizing, and inference-making. Metacognitive monitoring was encouraged through comprehension checks, rereading of challenging passages, and think-aloud activities modeled by the instructor.

At the post-reading stage, students participated in reflective discussions and completed written tasks, including essay writing and the construction of mental maps. While creating mental maps, students visually organized central themes, character traits, and cause–effect relationships in the narrative. This activity promoted synthesis, evaluation, and self-regulation, as learners were required to reflect on their comprehension and make decisions about the relative importance of textual information.

These activities were explicitly designed to activate students' schemata related to Spanish social and cultural values and concepts of happiness depicted in the story.

Results

Questionnaire results revealed frequent use of cognitive strategies such as guessing meaning from context, visualization, and rereading. Majority of the students also reported increased awareness of comprehension breakdowns and strategy adjustment, indicating growing metacognitive control.

Analysis of questionnaire responses revealed noticeable variation in the frequency and quality of strategy use among students. The majority of participants reported frequent use of cognitive strategies such as predicting, guessing meaning from context, rereading difficult passages, visualization, and activation of background knowledge. These students also demonstrated higher levels of metacognitive awareness, including monitoring comprehension and adjusting strategies when encountering difficulties.

A smaller group of students reported moderate use of reading strategies, selecting "sometimes" for several cognitive and metacognitive items. While these students demonstrated basic comprehension of the text, their essays and mental maps tended to be less detailed and showed more limited thematic development.

Essay analysis demonstrated students' ability to interpret abstract themes such as happiness, freedom, choice, and personal fulfillment. Mental maps showed structured organization of ideas and relationships, with several students revising their maps after rereading, reflecting active monitoring and evaluation.

Analysis of students' mental maps revealed meaningful patterns in how learners organized and interpreted textual information. Most students identified central concepts such as happiness, freedom, choice, and personal fulfillment as key topics, linking them to supporting events, character decisions, and consequences from the story. The structure of the mental maps demonstrated learners' ability to synthesize information and establish hierarchical relationships between ideas, indicating active cognitive processing. Furthermore, the selective inclusion of themes and events suggests metacognitive evaluation, as students had to decide which elements were essential for understanding the text. The use of mental maps also supported comprehension monitoring, as several students reported revising their maps after rereading certain passages. This behavior reflects ongoing metacognitive regulation and awareness of comprehension gaps. Overall, mental mapping proved to be an effective strategy for enhancing both comprehension and reflective engagement with literary texts in an EFL context.

Discussion

The purpose of this study was to explore how cognitive and metacognitive reading strategies, supported by schema theory, influence reading comprehension among EFL university students working with a literary text. The findings suggest that explicit strategy-based instruction fosters active engagement with the text, enhances metacognitive awareness, and supports deeper interpretation. One of the central findings is the variation in both the frequency and quality of strategy use among students. Learners who reported frequent use of cognitive strategies such as contextual guessing, rereading, visualization, and activation of background knowledge demonstrated more coherent comprehension outcomes. Their essays reflected interpretive depth, and their mental maps showed structured organization of themes and relationships. This supports Grabe's (1991) assertion that proficient reading involves coordinated use of linguistic knowledge, background knowledge, and higher-order cognitive skills. The results also highlight the critical role of metacognitive strategies in successful reading. Students who monitored their comprehension, reflected on understanding after reading, and adjusted strategies when encountering difficulties showed greater independence

and control over the reading process. This finding aligns with previous research emphasizing that metacognitive awareness distinguishes skilled readers from less skilled ones (Pressley, 2000; O'Malley et al., 1985). In contrast, students who employed strategies inconsistently tended to rely on surface-level comprehension, producing more descriptive than analytical responses. Schema theory provided an effective methodological framework for supporting comprehension of "The Happy Man", a text embedded in a specific cultural context. Pre-reading activities were designed to activate cultural schemata related to Spanish values, lifestyle, and concepts of happiness, facilitated students' ability to interpret characters' choices and motivations. The consistency between students' mental map and essay themes suggests that activating and reorganizing schemata played a key role in meaning construction, supporting the interactive model of reading. The use of mental mapping as a post-reading activity further reinforced both cognitive and metacognitive processes. Mental maps required learners to select, organize, and hierarchize information, thereby encouraging synthesis and evaluation. Students who revised their maps after rereading demonstrated active monitoring and regulation of comprehension, illustrating the recursive nature of strategic reading. These findings support Pintrich's model of self-regulated learning, which emphasizes planning, monitoring, and evaluation as central to effective learning. Importantly, the study indicates that success in reading comprehension is not merely a function of linguistic proficiency but is closely related to learners' strategic awareness and ability to regulate their reading behavior. The observed differences among students suggest that explicit instruction in cognitive and metacognitive strategies can help reduce disparities in comprehension by equipping learners with tools to manage difficulties more effectively. Despite its exploratory nature and small sample size, the study offers pedagogically meaningful insights. The classroom-based design allowed for close observation of learners' reading processes in an authentic instructional setting, supporting the ecological validity of the findings. However, results should be interpreted cautiously and not generalized beyond similar EFL contexts. Overall, the findings reinforce the view that reading is a cognitively and metacognitively driven process in which strategy instruction, schema activation, and reflective tasks such as mental mapping play a crucial role in developing proficient, autonomous readers.

Conclusion

The study examines the role of both cognitive and metacognitive strategies in enhancing English as a foreign language (EFL) intermediate level university students' reading comprehension, with special stress on schema activation and the use of the mental-mapping method. Reading is not a static decoding ability, but a complex dynamic, strategic and self-regulating process. Explicit instruction in cognitive strategies: skimming, scanning, contextual guessing, summarizing and visualization support students in constructing meaning. These strategies become effective when accompanied by metacognitive strategies, including planning, monitoring, self-regulation, questioning, and evaluation. As a theoretical framework schema theory proves that activation of student's prior knowledge during pre-reading stage facilitated comprehension of "The Happy Man" by S. Maugham, a text embedded in the context of contrasting English and Spanish specific society and culture. Mental mapping emerged as an effective method for integrating cognitive and metacognitive strategies, as this requires the readers to select, hierarchize, and evaluate textual information.

The study suggests that difficulties in reading are not solely attributable to language proficiency, but are closely linked to strategic awareness and the ability to regulate reading behavior. Methods such as mental-mapping combined with strategy-based teaching can help language learners to become more autonomous, confident and effective readers.

In conclusion reading as dynamic multifaceted skill cannot be attributed to one single skill, but results from integration of multiple cognitive and metacognitive strategies, which like the Sun and the Moon are inseparable.

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ОБОСОБЛЕННЫЕ ОПРЕДЕЛЕНИЯ И ПРИЛОЖЕНИЯ В ПРОИЗВЕДЕНИЯХ ХУДОЖЕСТВЕННОЙ ПРОЗЫ И В ПОЭТИЧЕСКОЙ РЕЧИ (СИНТАКСИЧЕСКИЙ И СТИЛИСТИЧЕСКИЙ АСПЕКТ)

Ким С.Ф.
доцент.
Самаркандский государственный университет имени Ш. Рашидова
Институт языков и культур народов Центральной Азии
Республика Узбекистан, г. Самарканд

STRUCTURAL AND SEMANTIC TYPES OF COMPLEX MONO-MEMBER AND POLY-MEMBER SENTENCES WITH THE COMPONENT "WHAT" IN THE WORKS OF M. YU. LERMONTOV

Kim S.
associate professor
Samarkand State University named after Sh. Rashidov.
Institute of Languages and Cultures of Peoples Central Asia.
Republic of Uzbekistan, Samarkand
DOI: 10.5281/zenodo.18738493

Аннотация

Статья посвящена обособленным определениям и приложениям, выявленным в произведениях русских писателей Горького А.М., Пушкина А.С., Некрасова Н.А., Чехова А.П. Внимание обращается на синтаксические и стилистические достоинства данных конструкций, являющихся весьма целесообразными приемами точного, краткого выражения определенного содержания. Подчеркивается важность их изучения на материале связного литературного текста, насыщенного обособленными конструкциями, что позволяет обращать внимание не только на форму (структуру) данных конструкций, но и на анализ их своеобразной (многозначной, совмещенной) синтаксической семантики и оценку стилистических достоинств данных оборотов.

Abstract

The article is devoted to isolated definitions and applications identified in the works of Russian writers Gorky M., Pushkin A.S., Nekrasov N.A., Chekhov A.P. Attention is drawn to the syntactic and stylistic merits of these constructions, which are very appropriate techniques for the precise, concise expression of specific content. The importance of studying them on the material of a coherent literary text, saturated with isolated constructions, is emphasized, which allows paying attention not only to the form (structure), these constructions, but also to analyze their unique (polysemantic, combined) syntactic semantics and evaluate the stylistic merits of these turns of phrase.

Ключевые слова: обособление, определение, приложение, совмещенная семантика, структура, антитеза, динамика пейзажа, портрет, текст описательного характера, характеристика персонажа.

Keywords: isolation, definition, application, combined semantics, structure, antithesis, landscape dynamics, portrait, descriptive text, characterization.

При изучении синтаксических конструкций, осложняющих структуру простого предложения, внимание приковывают обособленные определения и приложения, а именно: их форма выражения и, более всего, функция в составе предложения – синтаксическая и стилистическая.

Данные конструкции представляют собой лаконичные, экономные, но весьма выразительные обороты речи, подчеркнуто передающие атрибутивную семантику предмета, лица, явления. Однако, следует заметить, многие из них способны выражать не только определительное значение, но и могут иметь дополнительно различные обстоятельственные оттенки, что является, как известно, основанием их обособления и в препозитивном положении:

1) причины (*Фанатик своего дела*, **Кузьмичев** всегда, даже во сне и за молитвой в церкви … думал о своих делах (Чехов) – срвн.: … думал (почему?) – так как был фанатиком своего дела; *...истинный художник*, **Пушкин** не нуждался в выборе поэтических предметов…(Белинский);

2) образа действия (*Сопровождаемый офицером*, комендант вошел в дом (Пушкин) – срвн.: …вошел в дом (как?) – в сопровождении офицера;

3) условия (*Разбитый нами*, нет сомненья, царь не отвергнет примиренья (Пушкин) – срвн.: не отвергнет … (даже при каком условии?) – если будет разбит нами; Молодому **человеку**, *влюбленному*, невозможно не проболтаться (Тургенев);

4) уступительности (**Он** [Челкаш] – *вор, гуляка, оторванный от всего родного,* – никогда не будет жадным, низким, не помнящим себя (Горький) – срвн.: …не будет жадным … (несмотря на что?) – хотя он вор, гуляка …; *Еще прозрачные*, **леса** как будто пухом зеленеют (Пушкин) и др. – что является, как известно, основанием их обособления и в препозитивном положении.

Краткие по своей структуре, однако способные выражать совмещенную семантику – определительную (признак) и обстоятельственную (причину; образ или способ действия; уступительность; условие), – обособленные определения и приложе-

ния имеют свои преимущества по отношению к синонимическим параллельным придаточным предложениям: во-первых, лаконичностью способа выражения семантики, тогда как придаточные, являющиеся частью сложноподчиненного предложения, объемные, громоздкие; во-вторых, типичные придаточные определительные обычно выражают одно значение – признак предмета – и не осложняются дополнительной обстоятельственной семантикой, а типичные придаточные обстоятельственные не способны выражать определительную семантику (признак предмета), тогда как обособленные определения и приложения обладают такой способностью – выражать совмещенную семантику.

Многие лингвисты высоко оценивают стилистические достоинства рассматриваемых в данной статье синтаксических конструкций. Так, Пешковский А. М. дает им следующую характеристику: «Согласуемые обособленные члены и группы дают нам возможность нагружать наши выражения, не перегружая их, усложнять мысль, не усложняя в такой степени ее выражения. Это – легкое выражение мысли в отличие от тяжелого вооружения отдельных придаточных предложений» [3, *249*].

В современном русском литературном языке обособленные определения и приложения используются довольно широко. Мы наблюдаем их в различных речевых стилях, в различных литературных жанрах: в произведениях художественной литературы, в критических, публицистических статьях, в научных произведениях, в политической литературе, в докладах, учебниках, в газетном материале, в деловых бумагах и т.д.

Мы остановимся на использовании обособленных определений и приложений в произведениях художественной литературы. Данные синтаксические конструкции, выражая признаки предмета, лица, явления, чаще всего встречаются в текстах описательного характера: описывается обстановка, пейзаж, портрет, характеристика действующего лица.

Горький А.М., описывая в рассказе «Старуха Изергиль» пейзаж, на фоне которого героиня рассказывает легенду о Данко, довольно часто использует обособленные определения: «С моря поднимается туча – *черная, тяжелая, суровых очертаний, похожая на горный хребет*… В степной дали, *теперь уже черной и страшной, как бы приподнявшейся, скрывшей в себе что-то*, вспыхивали маленькие голубые огоньки… Это были очень странные голубые языки огня, *намекавшие на что-то сказочное*» [1, *79*].

В другом рассказе «Челкаш» [1, *123*] обособленные определения писатель использует с целью показать динамику пейзажа: сначала море – *«сонное, спокойное, гладкое», «мягкое, матово-черное», «молчаливое, пустынное», «бесконечное, могучее»*. Но вот появляется ветер, «хотя еще и легкий», и море изменяется, «*вдруг заигравшее чистой зыбью*»; на нем волны, *шаловливо плескавшиеся о борта лодки», «пока еще мелкие», «весело бросающие в борта светлые брызги, разбрасываемые ветром»*. Дальше море уже *«изрытое стаям волн, убранных пышной белой пеной».* Точно так же постепенно изменяется картина неба, облаков, и эти изменения Горький передает с помощью обособленных определений.

Много обособленных определений встречается и в рассказе «Песня о Соколе» [1, *165*] (во вступлении, где дан пейзаж летнего вечера на берегу моря): «Море – *огромное, лениво вздыхающее у берега,* – лениво и неподвижно в дали, *облитой голубым сиянием луны*. *Мягкое и серебристое*, оно слилось там… Горы, *поросшие деревьями*, *уродливо изогнутыми норд-остом*, …подняли свои вершины…, суровые контуры их округлились, *одетые теплой и ласковой мглой южной ночи.* …все звуки, которые нарушают тайную тишину, *разлитую вокруг вместе с голубым серебром сияния луны, еще скрытой за горными вершинами»* и т.д.

Иногда писатели используют данные выразительные обособленные конструкции для оформления антитезы (противопоставление). Так, при помощи обособленных определений М. Горький рисует картину гавани в начале рассказа «Челкаш», противопоставляя грузчиков, с одной стороны, и машины, созданные этими людьми, с другой: «До слез смешны длинные вереницы грузчиков, *несущих на плечах своих тысячи пудов хлеба в железные животы судов для того*, чтобы заработать несколько фунтов того же хлеба для своего желудка. Люди, *рваные, потные, отупевшие от усталости, шума и зноя*, и машины, *созданные этими людьми*, … – в этом сопоставлении была целая поэма жестокой иронии» [1, *125*].

В произведениях художественной прозы и в поэтической речи писатели и поэты используют прием широкого, концентрированного использования обособленных определений и обособленных приложений для создания портрета, характеристики действующих лиц, в результате чего получается краткая, но очень яркая, выразительная характеристика персонажа. Большим мастером этого приема является Пушкин. В романе «Евгений Онегин» [4, *61, 63, 163*] поэт особенно часто прибегает к данному приему.

Вот некоторые из характеристик героев романа:

1. характеристика Онегина:

Театра злой законодатель,
Непостоянный обожатель
Очаровательных актрис,
Почетный гражданин кулис,
Онегин полетел к театру…;

2. характеристика Истоминой, знаменитой балерины:

Блистательна, полувоздушна,
Смычку волшебному послушна,
Толпою нимф окружена,
Стоит ***Истомина***…;

3. характеристика Зарецкого, друга Ленского:

В пяти верстах от … деревни Ленского
Живет и здравствует еще доныне
В философической пустыне
Зарецкий*, некогда буян,*
Картежной шайки атаман,

Глава повес, трибун трактирный,
Теперь же добрый и простой
Отец семейства, холостой,
Надежный друг, помещик мирный
И даже честный человек… и мн. др.

Прием широкого, концентрированного использования обособленных определений и приложений наблюдаем и в произведениях Лермонтова М.Ю., Некрасова Н.А., Тургенева И.С., Толстого Л.Н., Чехова А.П., Горького А.М. и др. при описании персонажей:

Убаюканный ласковым пением
Средиземной волны, – …
Ты уснешь, *окружен попечением*
Дорогой и любимой семьи,
Ждущей смерти твоей с нетерпением.

И сойдешь ***ты*** в могилу…***герой***,
Втихомолку проклятый отчизною,
Возвеличенный громкой хвалой
(Н. Некрасов. Размышления у… подъезда) [2, *53 – 54*];

Пятый ***партнер***, *кухаркин сын Андрей, черный, болезненный мальчик, в ситцевой рубашке и с медным крестиком на груди*, стоит неподвижно и мечтательно глядит на цифры (А. Чехов. Детвора) [5, *315*] и мн. др.

Подводя черту нашим наблюдениям, следует отметить: иллюстративный (литературный) материал свидетельствует, что обособленные определения и приложения, как своеобразные выразительные, сильные, сжатые и гибкие синтаксические конструкции, являются весьма целесообразными приемами точного, краткого выражения определенного содержания. И если синтаксическая форма словосочетания – обособленные определения и обособленные приложения – соответствует данному содержанию, выражает его полно, точно, ярко, образно, мы с полным правом можем утверждать, что в данном случае наблюдается органическая связь грамматической формы (структуры) с содержанием (семантикой).

Факты широкого использования рассмотренных в статье синтаксических конструкций – обособленных определений и приложений – говорят о том, что они представляют собой одну из существенных особенностей грамматического строя русского языка. Своеобразие данных конструкций определяется: а) их промежуточным положением между обычными нераспространенными определениями и приложениями, с одной стороны, и придаточными предложениями атрибутивной семантики, с другой; б) лаконичностью, экономностью языковых средств, точностью, выразительностью и образностью передачи определительной (атрибутивной) семантики предмета, лица, явления.

Из сказанного вытекает: при изучении обособленных определений и приложений (данную работу желательно проводить на материале связного литературного текста, насыщенного обособленными конструкциями) следует обращать внимание не только на форму (структуру) данных конструкций, но – что особенно важно – обязательно анализировать их своеобразную (многозначную, совмещенную) синтаксическую семантику и оценивать стилистические достоинства данных оборотов, что будет содействовать развитию у обучающегося языкового чутья, формированию умений и навыков правильного употребления обособленных конструкций.

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POLITICAL SCIENCES

POST-NEW START STRATEGIC STABILITY: PREDICTABILITY, TRANSPARENCY, AND RESTRAINT

Szilagyi L.
International Relations Expert,
4iG Space and Defence Technologies, Budapest
https://orcid.org/0009-0006-8476-3428
Szenes Z.
Professor Emeritus, PhD (Military Science)
Ludovika University of Public Service, Budapest
https://orcid.org/0000-0003-1686-2273
DOI: 10.5281/zenodo.18738504

Abstract

The New Strategic Arms Reduction Treaty (New START) ended on February 5th, 2026, which raises critical questions about the future of nuclear weapons control and strategic stability. This analysis provides a review of New START through the lens of three stabilising functions – predictability, transparency, and restraint – and demonstrates how the treaty has mitigated worst-case war planning, reduced uncertainty, and decreased the incentive for competitive behaviour between the United States and Russia. In addition, the article examines the limitations of these functions, including partial scope, vulnerability to political crises, and inability to deal with the emergence of new technologies and other non-strategic nuclear forces. Using a functional review as a base, the paper analyses the future of strategic stability in a post-New START world and highlights which functions have the possibility of continuing and which functions are most at risk. The findings suggest that while predictability may endure in a weakened form, transparency and restraint are unlikely to survive without formal mechanisms, emphasising the need for flexible, function-specific approaches to nuclear risk management. By shifting the focus from treaty mechanics to stabilising functions, this study offers a novel framework for understanding the dynamics of strategic stability in a more complex and contested nuclear order.

Keywords: New START, Strategic Stability, Nuclear Arms Control, Post-Treaty Risk Management.

Introduction

The expiration of the New Strategic Arms Reduction Treaty (New START - officially the Treaty between the United States and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms) on 5 February 2026 marked a critical turning point for global nuclear arms control and international security. The last remaining bilateral agreement established legally binding limits on the number of deployed strategic warheads and delivery systems, as well as a framework for transparency and predictability between the world's two largest nuclear powers. New START had also provided legally binding limits on the development and deployment of nuclear weapons. The expiration, for the first time since the early 1970s, removed the constraints of any formal arms control regime from the American - Russian strategic nuclear forces.

The timing of New START's expiration significantly increased its importance given the extreme geopolitical deterioration, resulting from the war in Ukraine, the suspension of all dialogue regarding arms control, and the erosion of verification practices. Because New START did not serve only as a technical instrument to limit the size of nuclear arsenals, but also served as a stabilising mechanism, influencing expectations, reducing uncertainty, and limiting the risks of escalation, primarily through the establishment of limits on worst-case planning and misperceptions. Therefore, the expiration of the treaty has once again sparked controversy surrounding the future of nuclear arms control, specifically about the possible erosion of predictability, transparency, and restraint: the fundamental elements underpinning strategic stability. With the removal of the legal limits and transparency requirements of New START, both sides can increase the numbers of their deployed strategic nuclear forces, thereby increasing the potential for arms races, crisis instability, and strategic miscalculations.

This article argues that the importance of New START stems not so much from the quantitative limits of the treaty, but from the stabilising functions provided within the strategic relationship of the United States and Russia. "Stabilising functions" refer to those mechanisms through which arms control agreements reduce the potential for nuclear competition, crisis escalation, and strategic miscalculation. These functions operate by establishing certain behaviours, expectations, and planning assumptions among states, rather than simply limiting numerical capabilities.

By institutionalising predictability, transparency, and restraint, New START minimised uncertainty and limited the potential for escalation even when faced with political confrontation. Nevertheless, these stabilising functions were partial, and increasingly fragile; constrained by the limited scope of the treaty, its vulnerability to crises, and inability to account for the proliferation of emerging technologies and broader nuclear dynamics. Based on the function-based analytical approach, this article evaluates the role of New START in maintaining strategic stability and assesses the degree to which its stabilising effects will remain present in the

post-New START period. The central research question of this article – to what extent can the stabilising functions traditionally provided by bilateral arms control be maintained in the absence of New START? – necessitates an analytical model that transcends treaty compliance or continuity and emphasises the underlying mechanisms through which arms control influences state behaviour. Thus, a function-based methodology is particularly suitable to identify both continuities and discontinuities in strategic stability during periods of institutional breakdown.

Research methodology

The theoretical foundation of this analytical model is rooted in strategic stability theory which conceptualises stability as a condition in which the incentives for the initial use of force, arms racing, and crisis escalation are reduced due to a combination of material capabilities, information clarity, and behavioural constraints (Freedman, 2003). Unlike previous approaches that have treated arms control agreements as inherently stabilising, this approach disaggregates stability into three analytically distinct yet interdependent stabilising functions: predictability, transparency, and restraint. Each function corresponds to one of the specific theoretical mechanisms outlined in the deterrence, security dilemma, and institutionalist literature, thus enabling a systematic evaluation of how stability is created and potentially degraded over time.

Predictability is rooted in classical deterrence theory and concepts of crisis and arms race stability. According to Schelling and Halperin, stable deterrence depends not only on capabilities, but also on the ability of adversaries to be able to anticipate what those threats will be (Schelling & Halperin, 1961). Therefore, predictability, through reducing incentives for "worst case" planning by providing information regarding the number, composition, and development of offensive forces, assists in the building of a sense of confidence in one's capability to carry out a second strike. For the purposes of this analysis, predictability is defined by numerical ceilings, deployment guidelines, and notice requirements that allow for long term strategic planning. Consequently, the assessment of predictability after New START will involve determining whether the use of non-binding alternatives (such as unilateral announcements, existing force structures, or continued operation patterns), can serve as adequate substitutes for legally binding limits.

Transparency draws heavily on security dilemma theory and signalling theory, notably the works of Jervis and others that emphasise the likelihood that uncertain and/or misinterpreted adversary actions may lead to destabilising action–reaction dynamics even among countries committed to the status quo (Jervis, 1978). The transparency mechanisms of arms control (data exchanges, inspection, and notifications) function as a costly signal that restricts deception and reduces ambiguity surrounding both the capabilities and intentions of actors. As such, strategic stability theory suggests that transparency is especially critical for crisis stability, as it narrows the scope for misinterpretation during periods of heightened tension (Acton, 2018). In this context, the article assesses how the erosion of formal verification under New START affects informational symmetry and whether informal or unilateral transparency measures could reasonably serve as a replacement for institutionalised verification practices.

Restraint is linked to institutionalist and arms racing theories, which emphasise the role of formal rules in shaping long-term competitive behaviour. Authors like Glaser and Morgan suggest that unregulated strategic competition will typically generate self-sustaining arms racing dynamics based on hedging, uncertainty and "worst case" assumptions (Glaser, 2010). Arms control serves to maintain arms racing stability through the imposition of ceilings and qualitative limits that lower incentives for competitive growth in offensive forces and indicate an acceptance of sufficiency versus dominance. In addition to quantitative limitations, restraint is analysed as a behavioural norm reinforced by third-party constraints. The function-based approach allows for an evaluation of whether restraint can continue through unilateral self-restraint or normative expectations once legally binding obligations expire

In terms of methodology, the function-based approach enables a comparative examination of two temporal conditions, namely, the period under New START, and the post-New START environment. Treaty texts, official statements, compliance reports and analyses by experts are examined to determine how each stabilising function was established institutionally, how each function operated in practice, and at what point they became subject to political disruption. This framework does not treat treaty expiration as a binary event but rather permits a nuanced assessment of the degree to which each function continues to exist (function persistence), deteriorate (function degradation) or evolve (function transformation).

Importantly, this methodology directly addresses the research question by converting the analytical focus from the continued existence of the treaty to the continued existence of its stabilising effects. Strategic stability theory indicates that stability can continue in either weakened or informal forms when some mechanism remains viable, regardless of whether there exists a formal agreement. Transparency reduces asymmetries and misperception, predictability constrains reactive escalation, and restraint limits competitive pressure. All three of these functions, by reducing the risk of unintended and/or accidental escalation, serve to support the continuation of stability. By framing these mechanisms as stabilising functions, the paper demonstrates both the theoretical and practical significance of arms control agreements, as well as illustrates how treaties create stability through regulated interaction and behavioural constraints, rather than merely through legally established ceilings. Furthermore, this approach enables the identification of which elements of stability are most resilient, which are most dependent on institutionalisation, and where the greatest risks of destabilisation are likely to emerge in the post–New START era. Through bridging theoretical debate concerning strategic stability with practical policy analysis, the function-based framework provides a structured and theoretically

grounded method of assessing nuclear risk management in an increasingly restrictive arms control environment.

Features of New START

New START is an example of a post-Cold War attempt to create legally binding nuclear disarmament between the United States and Russia. The New Strategic Arms Reduction Treaty (New START) was signed in Prague in April 2010, entered into force in February 2011, and replaced the 1991 Strategic Arms Reduction Treaty (START I) that expired in December 2009 (U.S. Department of State, 2024). Its negotiation reflected a shared recognition that, despite the end of ideological confrontation, unconstrained strategic nuclear competition would continue to pose significant risks to international security.

New START was a bilateral agreement, subject to ratification in each state's domestic legislation, and based upon international law. Unlike previous arms control treaties, New START did not include a wide range of weapons systems but focused narrowly on deployed strategic offensive nuclear weapons. This limited scope was intended to provide a politically feasible and verifiable framework for monitoring the parties' compliance at a time when trust between the parties was fragile (Liang, 2024).

Initially, New START was concluded for a period of ten years, with the possibility of a single five-year extension. In February 2021, the United States and Russia agreed to exercise this extension, setting the treaty's expiration date on 5 February 2026 (Arms Control Association, 2021). Importantly, New START contains no further extension mechanisms, making its expiration a definitive endpoint.

At the core of New START were quantitative limits on strategic nuclear forces. Article III caped each party at:

- 1,550 deployed strategic nuclear warheads
- 700 deployed intercontinental ballistic missiles (ICBMs), submarine-launched ballistic missiles (SLBMs), and heavy bombers
- 800 deployed and non-deployed launchers in total.

Beyond limiting the numbers of these weapons systems, the New START also created a comprehensive verification and transparency regime. Article XI outlined the core elements of the verification and compliance process and established the use of National Technical Means (NTM) and Cooperative Verification Measures (CVM). Additionally, it included a Bilateral Consultative Commission (BCC) to address any implementation issues that may arise. Finally, Article XI created the legal authority for exchanging information necessary to support transparency and confidence in compliance, prohibited interference with each other's NTM, and the use of concealment methods that could hinder verification, thereby reinforcing mutual confidence in treaty implementation.

Crucially, Article XI linked verification to the treaty's broader transparency regime by authorising on-site inspections, data exchanges, notifications, and exhibitions, which are outlined in detail in the Protocol to the Treaty. By including verification as a legal requirement, rather than merely as a voluntary activity, Article XI institutionalised transparency as a stabilising factor, reduced uncertainty, deterred non-compliance, and provided each party with sufficient confidence in assessing the size and nature of the other's strategic forces. These mechanisms were designed to detect violations of the treaty, but also to reduce uncertainty and prevent misinterpretation of routine military activities.

In addition to the central limits and verification mechanisms, New START also addressed the sensitive issue of missile defence in a limited but stabilising way. While the treaty imposed no restrictions on either the United States or Russia regarding their respective missile defence programs, its preamble acknowledged the interrelationship between offensive and defensive strategic arms and reaffirmed that existing missile defence systems do not threaten the viability of strategic deterrence. Operationally, Article V prohibited the conversion of ICBM and SLBM launchers into missile defence interceptor launchers and vice versa. This provision prevented the rapid development of new capabilities in response to perceived threats and contributed to the predictability of military planning and budgeting. Although missile defence was not restricted by the limits of the treaty, the provisions related to the use of launchers for both strategic offensive and defensive purposes contribute to strategic stability by reducing uncertainty about launchers roles and future force expansion (Antonov, 2012).

Overall, New START has played a pivotal role in defining the current relationship between the United States and Russia concerning their strategic nuclear capabilities. By imposing legally binding limits on deployed strategic forces, it continued the trajectory of nuclear reductions begun at the end of the Cold War. It also preserved a critical degree of predictability and mutual visibility at a moment when other key pillars of the arms control architecture, most notably the Anti-Ballistic Missile (ABM) and Intermediate-Range Nuclear Forces (INF) treaties, had collapsed. New START's significance therefore extended beyond its numerical ceilings: it institutionalised regular interaction among military and technical experts, reinforced norms of restraint, and provided a stabilising reference point even amid profound political tension. In this way, the treaty functioned not only as a mechanism for limiting strategic arsenals, but also as a confidence-building instrument that helped manage strategic rivalry between the world's two largest nuclear powers.

New START and the Provision of Stabilising Functions

New START has promoted stability, not only through numerical reductions, but by performing a set of stabilising functions that shaped expectations, strategic force planning, and risk perceptions between the United States and the Russian Federation. It has established an expectation of predictability, transparency, and restraint among the two countries by mitigating the incentive for an arms race and the risk of miscalculations that arise from nuclear competition. Evaluating New START through these functions provides a more precise understanding of its stabilising effects than an

exclusive focus on warhead ceilings or compliance records.

Predictability

Predictability was one of New START's greatest contributing factors to stability. Through establishing clear, legally binding limits on deployed strategic warheads and delivery systems, it constrained the range of possible force postures available to both parties. At the time of the February 2018 New START implementation deadline, both the United States and the Russian Federation had achieved the treaty's central limits *(See Figure 1)*. These limitations reduced the uncertainty about the future size and configuration of their arsenals and allowed both sides to make long term strategic plans based on the assumption of a stable and predictable situation rather than assuming the worst-case scenario (Albertson & Sokov, 2023).

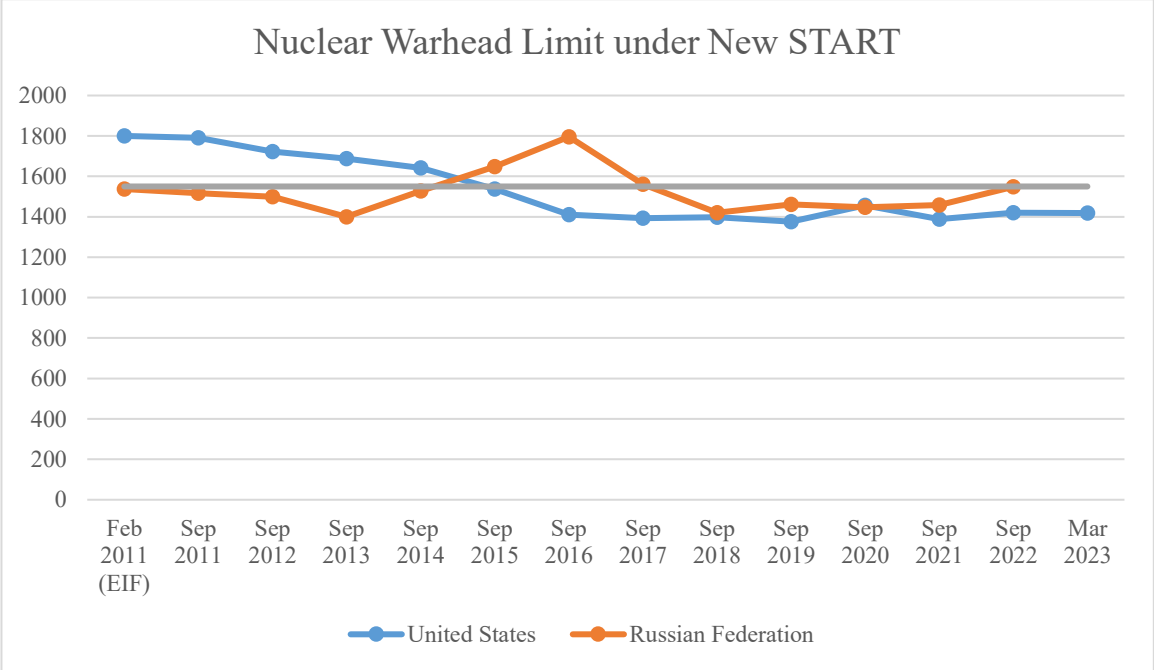

Figure 1. – Nuclear Warhead Limit under New START

Source: https://www.armscontrol.org/factsheets/new-start-glance

After 2023, no official New START compliance data is available since Russia suspended its participation in the treaty's verification. For 2024 and 2025, independent analysts provide open-source estimates of the United States and Russian nuclear arsenals, however, these figures account for the total estimated number of nuclear weapons, not simply the treaty-limited deployed strategic warheads, the total inventories include many more warheads in reserve or storage. (Kristensen, Korda, Johns & Knight, 2025). While New START limited deployed strategic warheads to 1,550 per side, the expert reports from the Federation of American Scientists indicate that both parties likely remained close to this limit through 2024 and 2025

According to Nuclear Notebook 2025, the United States had 1770 and 775 deployed warheads and delivery systems last year, while Russia had 1,718 warheads and 592 deployed weapon systems, respectively. However, in the field of tactical nuclear weapons, the Russian Federation had a nuclear capability seven times greater, which is a worrying issue, especially for Europe.

In addition to the numerical limits, predictability was supported by the regular exchanges of data and notifications concerning changes in strategic forces. This process allowed both sides to anticipate routine developments, such as the modernisation or redeployment of forces, without assuming that they were indicative of hostile intent. New START thus reduced the pressure to rapidly expand or modernise forces in response to perceived hostile actions (Vignard, ed., 2010).

Transparency

Transparency constitutes the second major stabilising function of New START. The treaty's verification mechanism, which included on-site inspections, data exchanges and notification obligations, permitted each side to obtain knowledge of the composition and deployment of the strategic nuclear forces of the other. Transparency accordingly reduced reliance on national technical means alone and lowered the risk of the misinterpretation of military activities (Woolf, 2020). Since the entry into force of the New START Treaty, and up to February 1, 2023, the two parties have conducted (U.S. Department of State):

- 328 on-site inspections,
- 25,449 notifications exchanged,
- 19 meetings of the Bilateral Consultative Commission, and
- 42 biannual data exchanges on strategic offensive arms subject to the treaty.

Through the establishment of a framework for the routine interaction of military and technical personnel, New START normalised the exchange of information between the two sides, regardless of whether there existed mutual trust. The exchanges facilitated a shared

understanding of the respective force structures and operational procedures, thereby enhancing confidence that the military activities observed by the parties were in conformity with the mutually agreed upon boundaries. As such, the transparency mechanisms under New START fulfilled not only a monitoring-compliance function, but also a confidence-building function critical to crisis stability (Patton, Podvig, & Schell, 2013).

The mechanisms of transparency also improved strategic communications by providing clarity to intent. In environments characterised by ambiguity, clarity is critical to mitigate the risk of escalation. The treaty's verification mechanism, therefore, reduced the likelihood that routine modernisation or exercises could be interpreted as preparation for first use or as escalatory coercion.

Restraint

To begin with, New START was a source of strategic stability as it institutionalised restraint in strategic nuclear rivalry. The treaty established legally binding constraints on strategic nuclear weapons; however, it also created a variety of political and reputational disincentives against violation or suspension of compliance. In this regard, the treaty was not only observed by its parties but also conveyed to the public that the parties were committed to share norms of prudent stewardship of their nuclear arsenals. Violation or suspension of compliance would have had serious implications for diplomacy and strategy. Furthermore, the treaty preserved the mutual recognition of strategic parity and shared vulnerability, both of which are essential elements of stable deterrence. Therefore, New START limited the possibilities for strategic advantage through rapid build-up and reduced incentives for destabilising strategies based upon acquiring escalation dominance.

New START clearly allowed for the replacement, upgrade, and modernisation of existing strategic offensive systems, as noted in Article V, so long as the new systems remained below the agreed ceilings and were made subject to transparency and verification measures. By establishing quantitative limits rather than qualitative attributes of strategic systems, New START incorporated restraint into the magnitude of competition rather than the technological content of it. This approach reflected a common view that modernisation is a regular and necessary part of maintaining credible deterrence capabilities and that unregulated increases in numbers pose a greater risk to strategic stability. Thus, modernisation under New START served strategic stability by ensuring forces remain effective and safe while preserving predictability and confidence in mutual restraint (Karakaev, 2023).

Taken together, predictability, transparency, and restraint illustrate how New START functioned as a stabilising instrument beyond its formal legal provisions. Although these functions did not eliminate rivalries or preclude political conflict, they diminished the strategic impact of those rivalries by limiting competitive pressures and reducing uncertainty. However, the extent to which New START's stabilising functions were effective depended on the level of political commitment and favourable security conditions; this represents a significant challenge when evaluating the limitations of the treaty and its eventual expiration date.

NEW START's Limitations in Maintaining Strategic Stability

Although New START provided some stabilising features, it was unable to maintain strategic stability either comprehensively or in face of political and technological changes. A similar functional framework (predictability, transparency, and restraint) reveals that New START's stabilising effects were limited, contingent and weakening. These limits help explain why the expiration of New START created considerable challenges to achieving strategic stability and why the treaty was insufficient as a long-term stabilising mechanism.

Limitations to Predictability

Despite its contribution to strategic predictability, New START imposed limits only on deployed strategic nuclear forces; therefore, many other aspects of nuclear competition remained outside the treaty's scope. Non-deployed warheads, reserve stockpiles, and non-strategic (tactical) nuclear weapons were not included in the treaty, thereby allowing each party to retain sizeable capacities above treaty limitations. This partial coverage reduced the treaty's ability to provide a comprehensive picture of overall nuclear posture and weakened predictability at the margins (Diakov, Miasnikov & Kadyshev, 2011).

New START's failure to address emerging technologies that continue to influence the basis for strategic decision-making further exacerbated limitations to predictability. New START did not account for hypersonic delivery systems, unmanned aerial vehicles (UAVs), new types of strategic platforms, or advanced missile defence systems, all of which increase the complexity associated with assessing survivability and second-strike credibility. As such, as these technologies develop, the assumption that numeric ceilings on traditional delivery systems became less reliable indicators of strategic balance (Erästö, 2021).

As a result, while New START stabilised certain quantitative aspects of strategic forces, it did not restrict the qualitative development of nuclear arsenals, creating an incentive for the parties to engage in planning based on uncertainty regarding future technological trajectories, thereby reintroducing elements of worst-case thinking that the treaty was originally designed to mitigate.

Disruption of Erosion of Transparency

Transparency mechanisms within New START were also susceptible to disruptions in politics and security. On-site inspections were suspended in 2020 due to the COVID-19 pandemic (Gottemoeller, 2022). Resumption of inspections following the pandemic was then impeded by the outbreak of the war in Ukraine in February 2022 (Bugos, 2022). Moreover, Moscow delayed the Bilateral Consultative Commission meeting for political and technical reasons in late 2022, which disrupted both compliance monitoring and discussions regarding advanced strategic nuclear delivery systems. It is worth noting that Russia did not formally withdraw from New START and asserted that it continues to comply with the core limits of the treaty (Ministry of

Foreign Affairs of the Russian Federation, 2023). However, the lack of on-site inspections and data exchange diminished the ability to effectively monitor compliance. After 2023, there was no access to officially verified figures on treaty-limited warheads. Information available for 2024–2025 comes from independently assessed expert estimates instead of official compliance data from New START.

The suspension of New START's verification mechanisms highlights the vulnerability of transparency measures to broader geopolitical events and shifts in political will. Russia's suspension of New START's verification mechanisms was framed in terms of the broader strategic environment, with Moscow arguing that U.S. actions threatened its national security and could not be separated from arms control obligations (Ministry of Foreign Affairs of the Russian Federation, 2023). This demonstrated that the effectiveness of verification depends on the willingness and continued cooperation of both parties.

The recent interruptions demonstrate that transparency is not solely dependent on technical capability, but on the larger political context, and without consistent cooperation, even legally binding mechanisms may lose much of their value in promoting stabilisation. The interruption of inspection activities reduced the level of trust among parties regardless of whether numerical limits on strategic forces were formally maintained. The interruption of on-site inspections and regular consultation weakened transparency, raised the risk of misperception, and reduced the ability to differentiate between routine changes to military forces and destabilising actions. Additionally, establishing verification mechanisms as part of broader political grievances creates a hazardous precedent by politicising arms control commitments and making them vulnerable to extraneous crises. As a result, the suspension accelerated the erosion of the arms control architecture and diminished New START's capacity to contribute to strategic stability in its final years (Williams, 2023).

Weakening of Restraint

New START's capacity to enforce restraint was similarly limited. The treaty did not limit the development of qualitative advances and more versatile strategic systems within current numeric limitations. Modernisation efforts, framed as replacement rather than expansion, continued to proceed largely unchecked, enabling the development of more capable and diverse strategic systems within existing numerical limits (TACC, 2025).

By the end of 2023, it is estimated that about 95 percent of Russia's nuclear triad consisted of modern weapons and equipment (Интерфакс, 2023). Moscow has also deployed several new systems in addition to ongoing repair/refurbishment of its nuclear triad, including Yars-M intercontinental ballistic missile, the new Avangard (SS-19 Mod 4) hypersonic glide vehicle (HGV), Kh-95 hypersonic air-launched cruise missile or dual-capable weapon systems, most notably the RS-28 Sarmat (SS-29) ICBM, 9M730 Burevestnik (SSC-X-9 Skyfall) intercontinental bomber, Status-6 Poseidon (Kanyon) underwater drone and 3M-22 Tsirkon (SS-NX-33) anti-ship drone (Johns & Mackenzie, 2024). Some of them were even tested in the ongoing Russian -Ukrainian war.

Similarly, the United States has also continued modernisation across all legs of its nuclear triad. On land, the Sentinel program is replacing the aging ICBMs; while the sea-based component is being upgraded through the construction of the Columbia-class submarines, life-extension programs for the Trident II D5 missiles, and the W93 warhead program which intended to be deployed on US SSBNs by 2040 (Center for Arms Control and Non-Proliferation, 2021). The Air Force is modernising its nuclear bomber fleet and strategic weapons, including upgrades to the Mk21 reentry vehicles, the W76-1/Mk4A warhead fuse program, and the development of new systems such as the B61-12 gravity bomb and the AGM-181 Long-Range Standoff Weapon, alongside the introduction of the B-21 Raider bomber (Airforce Technology, 2020).

Moreover, restraint under New START was inherently limited by the treaty's narrow scope, which placed quantitative ceilings on deployed strategic offensive arms but imposed no constraints on other nuclear capabilities. In recent years, this limitation has become increasingly salient. The United States has continued to advance missile defence programmes outside the treaty framework, most notably announcing the development of a next generation homeland missile defence architecture (often referred to as the "Golden Dome") intended to counter emerging threats. Missile defence has been regarded as a core component of strategic stability for many years, and Russian strategic thinking has consistently viewed unconstrained U.S. missile defence as a potential challenge to deterrence credibility (Bazylczyk & Freeman, 2025). Russia, for its part, has highlighted the development of novel strategic systems, including the nuclear-powered Burevestnik cruise missile, which some analysts see as a response to U.S. missile defence advances even though the system has been under development since at least 2018 (Starchak, 2026). These developments suggest that while New START imposed restraint on the number of deployed warheads, it did not prevent either party from pursuing qualitative advances and auxiliary capabilities that shape strategic balance. This pattern underscores how restraint under the treaty was partial and increasingly eroded by modernisation dynamics occurring beyond its formal limits.

Beyond the quantitative dimensions of modernisation, the weakening of restraint under New START also found expression in postures and signalling of nuclear behaviour. Since the beginning of the war in Ukraine in early February 2022, Russia has dramatically increased its nuclear rhetoric; carried out high profile nuclear exercises; and issued repeated reminders of its nuclear weapons capabilities in official public declarations (Arndt & Horowitz, 2022). Moscow revised the nuclear strategy in November 2024 authorizing the government to use nuclear weapons even in the event of a serious attack with conventional weapons. Although none of these actions altered the accountable forces under New START, they indicated an unwillingness to restrain behavioural choices, and a greater reliance on nuclear deterrence to exert political influence. These examples of signalling can be viewed as a form of strategic hedging, which allows for the preservation of escalatory options, and the prevention of foreign intervention, in an environment of increasing uncertainty. Therefore, the restraining effect of New START did not weaken only

through unregulated modernisation but also through changing nuclear postures, and declaratory practices that lowered the nuclear threshold, in general, in strategic dialogue.

Finally, restrain was further weakened by the treaty's purely bilateral structure. There were no constraints from third parties, especially from other nuclear-armed countries; therefore, the incentives to maintain long-term restraint decreased, as strategic planning became increasingly based on unconstrained actors outside of the treaty framework (e.g. China). This condition contributed to the view that bilateral limits, although fair, were insufficient in a wider strategic environment.

Over the years, there have been repeated efforts to extend nuclear arms control to include countries beyond the traditional U.S.–Russia bilateral framework. These attempts reflect an increasingly complex and competing multipolar nuclear order. Multilateralising arms control proposals have usually included either a UN Security Council P5 configuration, including the five recognised nuclear-armed countries under the Non-Proliferation Treaty, or a trilateral configuration including the United States, Russia, and China (Ryabkov, 2020). Most recently, U.S. President Donald Trump stated he wanted to begin nuclear arms control discussions with Moscow and Beijing and ultimately cut their defence budget expenditures that are being spent on nuclear (Shalal & Holland, 2025). According to Trump, the necessity for such a strategy lies in the fact that China intends to at least double its nuclear arsenal over the next decade, while Russia is advancing the development of expensive, destabilising delivery technologies. However, China expressed reluctance to participate in multilateral negotiations until Russia and the U.S. significantly decrease their respective stockpiles (Reif & Bugos, 2020). Similarly, Dmitry Peskov, Russian spokesman, stated that no specific negotiations have occurred yet, and it is still unclear when such contacts may take place (Интерфакс, 2025).

Additionally, the uncertainty regarding the future of New START has incentivised states to pursue hedging strategies. Within the context of nuclear arms control, hedging is defined as actions taken by states to preserve or increase future strategic options under conditions of uncertainty, without immediately violating current legal constraints. Instead of openly expanding numbers, hedging generally includes qualitative upgrades, the development of alternative delivery systems, stockpile management practices, or investment in capabilities that would allow for the rapid expansion of military forces if legal or political restraints are eliminated. Thus, hedging represents a loss of confidence in the continued viability of arms control agreements and signals a state's preparation for a less constrained strategic environment. For example, during the last few years of New START, both the United States and Russia engaged in behaviours that were indicative of strategic hedging, which represented a decline in confidence in the long-term viability of the treaty.

As previously described, the limitations of New START indicate that the treaty's stabilising functions were decreasingly able to perform effectively due to ongoing conflicts, technological advancements, and structural shifts in the nuclear environment. As such, while New START did make significant contributions to stability, the limitations identified above demonstrate that the treaty's stabilising functions were increasingly limited by constraints in the areas of politics, technology, and the nuclear environment that limited its durability. *Table 1* summarises the extent to which New START contributed to predictability, transparency, and restraint, while also highlighting the areas in which these functions proved incomplete or fragile. This comparative assessment provides the analytical foundation for evaluating prospects for strategic stability following the treaty's expiration.

New START's Contribution to the Stabilising Functions

Stabilising Function	***How New START Contributed***	***Where New START Fell Short***
Predictability	• Legally binding ceilings on deployed strategic warheads and delivery systems; • Regular data exchanges and notifications; • Reduced incentives for worst-case force planning.	• Coverage limited to deployed strategic systems; • Exclusion of non-strategic nuclear weapons and reserve stockpiles; • No regulation of emerging technologies (e.g. hypersonic).
Transparency	• On-site inspections and verification regime; • Institutionalised information exchange beyond national technical means; • Reduced misinterpretation of routine military activities.	• Suspension of inspections during pandemic and political crises; • Politicisation of verification procedures; • Transparency weakest precisely under crisis conditions.
Restraint	• Legal and normative limits on force expansion; • Political and reputational costs for non-compliance; • Reinforcement of strategic parity and mutual vulnerability.	• No constraints on qualitative modernisation; • Bilateral limits in a broader unconstrained nuclear environment; • Incentives for hedging behaviour as expiration approached.

Source: edited by the authors

Strategic Stability After New START: Prospects for Stabilising Functions Without Formal Constraints

The expiration of New START on February 5th, 2026, marked the first time since the early 1970's that neither the United States nor the Russian Federation have legally binding limits on the number of deployed strategic nuclear weapons. Although the disappearance of formal limits has created widespread concern regarding the possibility of renewed arms races; it should be emphasised that there remains a distinction between the loss of formally agreed upon limitations and the total collapse of strategic stability. Each party continues to maintain their existing force structures, the long-standing doctrine of mutual deterrence, and the numerous systems for commanding and controlling forces that collectively support a predictable and cautious atmosphere. However, the elimination of treaty-based limits creates new uncertainties in the planning horizon, specifically regarding force expansion, reserve stockpiles, and modernization.

Within this context, assessing the prospects for post-New START stability will require an assessment of the underlying stabilising functions (predictability, transparency, and restraint) that the treaty previously performed. An examination of which functions are expected to survive the expiration of the treaty and those that are most susceptible to decline will allow an estimation of the boundaries of strategic stability / instability in the absence of formal bilateral constraints.

As a stabilising function, predictability is likely to be the most resilient element of post-New START strategic stability, although it will likely exist in a partially and conditionally sustainable state. Prior to the expiration of the treaty, the numerical limits and notification requirements in the treaty provided each party with a clear framework for anticipating the quantity and configuration of the other party's deployed strategic nuclear forces. Some degree of predictability may be preserved after the end of treaty by continued existence of current force structures, long-standing deployment patterns, and mutual acceptance of strategic parity. The rationale behind this thinking was exemplified in Russia's unilateral suggestion to continue abiding by the New START's central numerical limits for one additional year following the treaty's expiration, if the United States reciprocates (President of Russia, 2025). Such action would help to ensure that the current force base exists and would thus minimise uncertainty concerning rapid qualitative changes in either party's deployed nuclear forces and support longer term strategic calculations. However, unilateral declarations, public statements related to the size of deployed forces, and continuing operational norms can only provide limited guidance to planners and therefore illustrate the inherently fragile and reversible nature of post-treaty predictability.

The absence of legally binding limits introduces significant uncertainty. Both the United States and Russia currently have the formal authority to increase the size of their deployed strategic nuclear arsenals, to withdraw warheads from reserve stockpiles, and to accelerate modernisation programs without providing advance notice to the other party. The increased ambiguity will lead to growing probability that each party will prepare for the worst-case scenario and thus engage in behaviours designed to hedge against such eventualities (SIPRI 2025), such as maintaining excess reserves and/or developing flexible launch platforms. Thus, while some degree of predictability is likely to remain following the expiration of the treaty, it is likely to be weaker and more conditional in its nature, sufficient to prevent immediate crisis instability, but insufficient to fully anchor long-term strategic decision-making processes.

New START institutionalised transparency by establishing inspection regimes, data exchanges, and notification procedures. Transparency is likely to be the most vulnerable stabilising function following the expiration of the treaty. National Technical Means, such as satellite monitoring and signal intelligence, will undoubtedly provide some level of insight into the current disposition of forces of the opposing party; however, they are unlikely to provide the same depth and credibility of verification as treaty-based verification (Gleason & Riesbeck, 2020). On-site inspections, telemetry exchanges, and routine notifications provided both parties with objective evidence of compliance, as well as reinforced the mutual confidence that routine military actions were not indicative of hostile intent. Absent these mechanisms, both parties will experience increased uncertainty regarding the operational readiness of the opposing party, the pace of their force modernisation efforts, and the composition and size of the reserve stockpiles (Morić & Korda, 2025).

The vulnerability of transparency is most apparent when political tensions are high, or during times of military tension. Under the experience of the New START Treaty, we have seen that verification systems can be suspended or become politically charged, and without a formal treaty, informally established systems will be even less durable. During crisis situations, unverified information can lead to the amplification of "worst case" thinking and therefore increase the potential for error and unintended escalation. While some form of transparency may still exist, albeit in a limited, ad-hoc manner, transparency's role in the post-treaty period is unlikely to provide the same stabilising effects that existed prior to the treaty's expiration. From a practical perspective, the loss of transparency creates a significant gap in the mechanisms that previously reduced strategic uncertainty and thus reduce planners' and decision makers' reliance on incomplete intelligence and assumptions, rather than factual evidence.

Restrain, the last stabilising function, will face the largest challenges in the post-New START environment. Although New START imposed legally binding restrictions on the number of deployed strategic warheads and delivery systems, there were no restrictions placed upon modernisation programs, non-deployed stockpiles, or qualitative improvements to existing arsenals. After the treaty expired, both the United States and Russia possess the formal right to expand or diversify their nuclear forces without being bound by any

treaty restrictions. Thus, there exists a natural inclination to engage in behaviours that create uncertainty and can erode stability. The expansion of U.S. missile defence capabilities and Russia's development of systems such as the Burevestnik can be interpreted as forms of strategic hedging associated with the gradual erosion of restraint. Neither development necessarily implies an immediate return to a situation where nations will race to build up their respective nuclear arsenals numerically, but both indicate an increasing concern regarding the long-term durability of mutual limitations and second-strike assurances in a post-treaty environment. The development of U.S. missile defence capability has introduced concerns regarding possible future offensive-defensive imbalance issues. Similarly, Russia's development of novel delivery systems appears to be an attempt to protect against such potentialities. These two developments combined demonstrate how a decline in confidence in arms control agreements creates an incentive for nations to maintain deterrence using insurance capabilities, rather than by relying on reciprocal restraint.

The bilateral nature of New START also meant that the restraint imposed by the agreement applied only to the U.S.-Russian dyad; all other nuclear armed states were outside the bounds of its provisions (Pifer & Tyson, 2016). Given the current strategic environment, this absence of third-party constraints further reduces the likelihood of continued self-restraint (Wright, 2023). Absent legal obligation, restraint will depend almost entirely on voluntary adherence to norms, reputational concerns, or reciprocal signalling: mechanisms that are inherently weaker and more susceptible to political or security crises. As a result, the elimination of formal limits is likely to increase the incentive for expanding one's arsenal and engaging in hedging behaviour, which could produce increased uncertainty and encourage competitive behaviours that New START previously mitigated.

Conclusion

This article addressed the question to what extent the stabilising functions of bilateral arms control (predictability, transparency, and restraint) can remain after the expiration of New START. Drawing on strategic stability theory and a function-based analytical framework, the findings indicate that these functions are not equally resilient once formal institutional constraints are eliminated. While prior arms control agreements have decreased the security dilemma through reduced uncertainty and by moderating competitive behaviour, the expiration of New START has exposed the unequal resilience of the stabilising mechanisms institutionalised by those agreements.

From a theoretical standpoint, predictability is the least institutionally dependent stabilising function. Predictability, even in the absence of formal treaties, can be preserved to some degree by structural factors such as relatively stable force structures, enduring deterrence relations, and shared understandings of strategic parity. Such dynamics are consistent with realist theories that expect that when mutual vulnerability exists among states, there will continue to be incentives to avoid destabilising arms races. However, such predictability is inherently less robust and more contingent than treaty-based predictability, since it lacks the formal ceilings, verification, and enforcement mechanisms that provide anchoring expectations over time.

By contrast, transparency and restraint are far more reliant on institutionalised cooperation. Strategic stability theory emphasises that transparency reduces the risk of misperception and worst-case planning by transforming private information into shared knowledge, while restraint depends on credible commitments that alter incentives for competitive expansion. Transparency could be partially maintained through voluntary data exchanges or confidence-building measures; restraint might be encouraged through reciprocal signalling or reputational incentives, for instance. However, the suspension of New START verification illustrated how quickly transparency is broken in the absence of binding rules, while ongoing modernisation, missile defence developments, and intensified nuclear signalling demonstrated how restraint erodes when institutional constraints weaken. In a self-help system characterised by heightened uncertainty, states increasingly favour hedging strategies that preserve flexibility over cooperative self-limitation.

The findings of this research therefore suggest that strategic stability in the absence of New START will be incomplete, fragile, and highly sensitive to political context. While bilateral arms control may be theoretically relevant as a means to manage the security dilemma, the ability of bilateral arms control to preserve the stabilising functions will depend upon both the design of institutions and the broader strategic context. Therefore, if comprehensive treaties do not exist, function-specific mechanisms such as voluntary data exchanges, informal confidence-building measures, reciprocal signalling, and reinforcement of normative expectations, may replace formally negotiated arms control in sustaining aspects of predictability, transparency, and restraint. However, such mechanisms will not possess the same level of durability and credibility as verification regimes established under legally binding treaties.

Ultimately, the expiration of New START underscores a central theoretical insight: strategic stability is not produced by treaties per se, but by the stabilising functions they embed within the strategic interaction of states. When those functions are no longer institutionalised, stability becomes increasingly dependent on informal practices, shared norms, and political will, making it more vulnerable to crisis and miscalculation. The opportunity now exists to move to a non-treaty stabilization mechanism: Moscow has offered to stay within the limits of New START for at least a year. If the United States agrees to start talks on the full range of factors affecting nuclear dangers, there will be a hope to maintain some strategic stability in a more complex and contested nuclear world.

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PSYCHOLOGICAL SCIENCES

INTERGENERATIONAL DIFFERENCES IN VALUE ORIENTATIONS IN CONDITIONS OF SOCIAL TRANSFORMATION: AN EMPIRICAL STUDY

Podborschi A.
Clinical Psychologist, PhD Candidate
Independent International University of Moldova
ORCID: 0000-0002-1652-2458
DOI: 10.5281/zenodo.18738522

Abstract

This article presents a comparative analysis of the motivational value types among Baby Boomers, Generation X, Y, and Z in the context of socio-cultural transformation in contemporary Moldovan society. The theoretical framework of the study is Schwartz's theory of basic human values**.** Empirical data were collected using the Schwartz Value Survey (adapted by V. N.Karandashev), allowing for the identification of intergenerational differences in value priorities. The results reveal statistically significant differences across several value types. Baby Boomers are characterized by a predominant orientation toward Conservation values—including Security, Tradition, and Conformity. Generation X demonstrates a combination of Conservation and Universalism, reflecting both stability and concern for broader social well-being. Generation Y exhibits strengthened Openness to Change and Self-Enhancement values, particularly Self-Direction, Achievement, and Stimulation. Generation Z is distinguished by high prioritization of Self-Expression, Hedonism, and Autonomy, alongside comparatively lower emphasis on hierarchical Power and Authority. Overall, these findings reflect a generational trend from preservation-oriented (Conservation) toward more individualistic and self-directed value orientations (Openness to Change and Self-Enhancement)**,** illustrating the influence of socio-cultural transformation on intergenerational value patterns in Moldova.

Keywords value orientations; basic human values; Schwartz's theory; generations; Baby Boomers; Generation X; Generation Y; Generation Z; intergenerational differences; sociocultural transformation.

Values constitute a key regulatory factor in social interaction and represent a fundamental element of culture. They shape individual ideals and guide behavioral choices within the social environment. Intergenerational continuity, as a mechanism for transmitting cultural heritage and value priorities, is undergoing significant transformation in contemporary society. Socio-economic and cultural changes contribute to shifts in value hierarchies, particularly among younger generations, who increasingly prioritize values associated with **openness to change** and **self-enhancement**, such as **self-direction, achievement**, and career-related aspirations. In contrast, older generations tend to emphasize values of **conservation,** including **tradition, conformity**, and **security**. This divergence in value priorities may contribute to an intergenerational value gap, uneven patterns of interaction, and feelings of marginalization among older adults [1].

Within the framework of the present study, a generation is understood as a socio-demographic and cultural–historical cohort of individuals shaped by shared conditions of socialization within a specific historical period. These common formative experiences contribute to similarities in value orientations and behavioral patterns (Mannheim, 1952; Strauss & Howe, 1991; Inglehart, 1997) [2,3,4].

According to Schwartz (1992), values represent **desirable, transsituational motivational goals** that serve as guiding principles in people's lives. They express fundamental human requirements, direct behavior, and provide criteria for evaluating events, actions, and social phenomena [5].

Inglehart conceptualizes values as relatively stable orientations formed during the process of socialization and reflecting the socio-economic conditions under which a generation develops. These value orientations shape individuals' life priorities and behavioral patterns [4].

Since values are primarily transmitted through socialization, the family plays a central role in this process. It is within the family that children acquire interaction skills and internalize social norms and value priorities. However, contemporary society is characterized by rapid change, which inevitably transforms the forms and functions of the family and modifies patterns of intergenerational relationships.

The relevance of the issue under consideration is growing in the context of contemporary social change, in which strategies of intergenerational transmission of traditional and collectivist-oriented cultural values continue to persist. This occurs alongside the emergence of a modern social reality increasingly oriented toward the future and emphasizing personal autonomy, individual self-determination, and independence. In the socio-psychological context, intergenerational transmission is understood as a process of transferring and transforming socially significant values, accompanied by changes in roles, responsibility, and mutual dependence between older and younger generations [6].

The aim of the study is to identify and analyze the characteristics of axiological orientations among representatives of different generations living in the Republic of Moldova.

The object of the study is intergenerational society as a system comprising cohorts of different generations (Baby Boomers, Generation X, Generation Y, and Generation Z) whose interaction contributes to social

dynamics through the transmission and transformation of value priorities.

Subject of the study.

The subject of the study is the process of intergenerational transmission and transformation of values, namely how value orientations change and are reinterpreted in the perceptions, beliefs, norms, and ideals of representatives of different generational groups in contemporary society.

The sampling framework for the empirical study was based on the generational periodization developed by W. Strauss and N. Howe and adapted to the sociocultural realities of post-Soviet societies by E. Shamis and E. Nikonov [7]. Belonging to a particular generation is determined by the commonality of: (a) a historical era; (b) shared beliefs and behavioral patterns; and (c) a sense of generational identity formed through collective experiences with one's peers [8].

The sample consisted of 200 participants. At the time of the study (2022), respondents ranged in age from 19 to 78 years. The Baby Boomer generation included individuals aged 59–78 years; Generation X, 38–58 years; Generation Y (Millennials), 20–37 years; and Generation Z, operationalized in this study as individuals aged 17–19 years.

To address the research problem, Schwartz's theory of basic human values was applied, as it provides a conceptual framework for examining intergenerational differences in value priorities and their transmission. Values were measured using the Schwartz Value Survey, adapted by V. N. Karandashev [9].

At the individual level, values are understood as motivational goals that guide people's lives. The relationships among values reflect the psychological dynamics of conflict and compatibility experienced by individuals in the course of everyday value realization [6, pp. 73–74]. Values possess both qualitative content and quantitative importance: the content dimension determines which principles and behavioral goals are considered significant, whereas the quantitative dimension reflects the relative priority of a value for the individual [10].

In accordance with Schwartz's model, the following ten motivational value types were distinguished: **Power, Achievement, Hedonism, Stimulation, Self-Direction, Universalism, Benevolence, Tradition, Conformity, and Security** [7].

Schwartz and Bilsky proposed distinguishing values according to the interests they primarily serve.

1. **Values expressing individual interests**, including the motivational types of **Power, Achievement, Hedonism, Stimulation, and Self-Direction.**
2. **Values expressing group interests,** including **Benevolence, Tradition, and Conformity.**

Two value types—**Universalism** and **Security**—address both individual and collective concerns, as they relate to the welfare of all people and to safety at both the personal and societal levels [11].

In addition, researchers have identified major patterns of value conflict within Schwartz's circumplex structure:

1. **Conservation values** (Security, Conformity, Tradition) are opposed to **Openness-to-Change values** (Stimulation, Self-Direction).
2. **Self-Transcendence values** (Universalism, Benevolence) conflict with **Self-Enhancement values** (Power, Achievement, Hedonism), which emphasize personal success and dominance.

To compare mean value priorities across generations and identify statistically significant differences, a one-way analysis of variance (ANOVA) was conducted. Data were processed using SPSS (version 25), with Bonferroni correction applied for multiple comparisons. Mean scores for each motivational value type were calculated, and value priorities were ranked within each generational group.

Results

The empirical findings reveal generational differences in the structure of value orientations (Table 1).

Table 1.

Significant differences in motivational value types among generations

Generations	**B/b**	**X**	**Y**	**Z**	**B/b-X**	**B/b-Y**	**B/b-Z**	**X-Y**	**X-Z**	**Y-Z**
Conformity	3,26	3,55	3,67	3,75	-	-	+ P=0,039	-	-	-
Tradition	2,70	5,67	3,12	3,45	-	-	+ P=0,002	-	-	-
Benevolence	3,80	3,95	3,98	3,71	-	-	-	-	-	-
Universalism	3,57	4,02	3,96	3,75	-	-	-	-	-	-
Self-Direction	3,51	3,92	4,20	4,08	-	+ P=0,001	-	-	-	-
Stimulation	2,24	2,67	3,10	3,46	-	+ P=0,000	+ P=0,000	-	+ P=0,001	-
Hedonism	2,43	2,83	3,53	3,83	-	+ p=0,001	+ P=0,001	-	-	-
Achievement	2,80	3,12	3,66	3,84	-	+ P=0,000	+ P=0,000	-	+ P=0,001	-
Power	1,95	2,34	2,80	3,40	-	+ P=0,001	+ P=0,000	-	+ P=0,000	-
Security	3,76	4,01	3,96	3,73	-	-	-	-	-	-

The analysis of motivational value types revealed relatively few statistically significant differences between the Baby Boomer and Generation X cohorts, suggesting a general continuity in their value priorities. However, significant variation was observed particularly in the value of **Tradition,** which was more strongly emphasized by Generation X. Overall, both cohorts demonstrate a shared orientation toward values related to **conservation,** including stability, family responsibility, and social order.

A comparable tendency was found in the comparison between Generations Y and Z. These younger cohorts exhibit broadly similar value profiles shaped by common socialization conditions in the context of rapid technological development and globalization. Nevertheless, significant differences emerged in certain values associated with **openness to change** and **self-enhancement,** such as **stimulation** and **power**, which were more strongly expressed among Generation Z.

The most pronounced generational differences were identified between Baby Boomers and Generation Y in the motivational value types of **Self-direction, Stimulation, Hedonism, Achievement, and Power.** These values belong to the higher-order dimensions of **openness to change** and **self-enhancement**, reflecting a stronger orientation of Generation Y toward autonomy, personal success, and enjoyment. In contrast, Baby Boomers tend to place greater emphasis on values associated with **conservation**, including stability, tradition, and social responsibility.

Significant differences between the Baby Boomer and Generation Z cohorts were found in the **motivational value types** of Conformity, Tradition, Stimulation, Hedonism, Achievement, and Power. These differences reflect socio-cultural transformations associated with digitalization, globalization, and expanded access to information, which shaped Generation Z. Unlike Baby Boomers, Generation Z tends to emphasize individuality, self-expression, and personal growth, rather than strict adherence to traditional norms.

Overall, the identified intergenerational differences in value priorities can be explained by the historical, social, and cultural conditions of socialization. At the same time, values associated with **openness to change** tend to decrease with age, whereas **conservation values** generally increase [12].

Significant differences between Generations X and Z were observed in the motivational value types of Stimulation, Achievement, and Power. These differences may be attributed to divergent socialization conditions, the pace of social change, and levels of technological development. Generation X, socialized under relative institutional stability and limited career mobility, emphasizes **Conservation** values and structured achievement within traditional social hierarchies. In contrast, Generation Z, socialized amid digitalization and globalization, demonstrates stronger **Openness to Change** and **Self-Enhancement,** favoring flexible career paths, innovation, and rapid self-realization.

Differences in **Power** also reflect changing perceptions of authority: Generation X tends to view Power in hierarchical and normative terms, whereas Generation Z associates it with the capacity to influence and transform social norms and institutions.

No significant differences were found among generations in the motivational value types of **Benevolence, Universalism, and Security,** indicating that values related to care for others, social and environmental responsibility, and personal and family well-being remain stable.

Across Baby Boomers, Generation X, and Generation Y, **Security** was the highest-rated value (M = 6.53, 6.78, 6.47, respectively), reflecting the importance of stability and protection. **Respect for parents and elders** (Conformity) is most pronounced in Generation Z (M = 6.68), likely associated with ongoing cultural and moral socialization and partial material dependence on parents. This value is also highly ranked among Baby Boomers, consistent with socialization within stricter normative hierarchies that emphasized respect for elders.

Across all generations, **Security-related values**, including items such as cleanliness and a healthy lifestyle, were highly rated (M = 6.35–6.66), reflecting their fundamental role in ensuring physical well-being and a sense of safety. This pattern aligns with the emphasis on **Conservation values** in Schwartz's theory.

The value of **World Peace** (Universalism) is highly significant for representatives of the three older generations, with Generation X (M = 6.60) ranking it as the most important. This may reflect their conscientiousness and engagement in broader social and political processes. Generation Z also values peace and harmony, though these priorities appear somewhat secondary to values related to personal experience, self-realization, and individual growth.

The value of being **successful** (Achievement) is most pronounced in Generation Z (M = 6.66), reflecting a strong orientation toward self-realization, personal achievement, and competitiveness in a globalized, digital environment. This value is also relatively high among Baby Boomers (M = 6.02), whereas Generations X and Y exhibit it to a lesser extent, possibly reflecting a greater emphasis on traditional work ethics, responsibility, and social obligations over individual career success.

Overall, the value structure of Generation Z is characterized by a stronger orientation toward **individualism, self-expression, personal achievement, and enjoyment of life.** Socialization in the context of digitalization, globalization, and active engagement with social media has contributed to heightened attention to personal desires, freedom of choice, and the development of an individual identity, corresponding to higher scores on **Openness to Change** and **Self-Enhancement.**

Among Generation Z, the highest-ranked value is **Hedonism,** reflecting a focus on personal needs, self-realization, and the pursuit of enjoyment. Items such as "enjoying life" are also highly rated (M = 6.49), indicating an orientation toward comfort, positive experiences, and subjective well-being, consistent with the increasing cultural emphasis on mental health and personal well-being.

At the same time, Generation Z continues to place importance on **Conformity-related values,** such as respect for elders, reflecting the continuity of traditional norms and the enduring role of family support, despite the cohort's overall individualistic orientation.

According to M. J. Twenge (2017), the phenomenon of "emerging adulthood" reflects a cultural shift toward individualism, prolonged parental support, and delayed financial independence, which may contribute to extended dependence on family resources, even among those with higher incomes.

Generation Z demonstrates notable transformations in attitudes toward family and marriage. Individuals in this cohort tend to postpone marriage, and traditional family forms are increasingly supplemented or replaced by alternative arrangements. Nevertheless, family remains an important social unit, although formal registration is no longer the sole benchmark. These patterns correspond to values of **Self-Direction, Hedonism, and Achievement,** reflecting an orientation toward self-realization, personal comfort, and individualized life strategies. Such strategies are facilitated by digitalization and social media, which expand opportunities for choice and self-expression, but also introduce new social risks and value conflicts.

The **Power value** is generally the least prioritized across generations, although its relative importance increases in younger cohorts, particularly Generation Z (M = 3.74). For Baby Boomers, Generation X, and Generation Y, Power remains minimal, reflecting an orientation toward **collectivism** and traditional social roles. Generation Y places slightly more emphasis on Power, while Generation Z assigns the highest significance to this value, likely reflecting interest in influence within digital spaces and adaptation to globalization and rapid social change.

The **Stimulation value,** representing a preference for a varied and dynamic life, receives low mean ratings across all generations (M = 2.66). Among Baby Boomers, it is the least significant value, consistent with their orientation toward stability and order. For Generation Z, Stimulation is more pronounced (M = 4.23), reflecting the need to adapt to accelerated social, technological, and political changes.

The value of **Authority**, as an aspect of Power, illustrates generational attitudes toward formal hierarchical roles. Among Baby Boomers, Authority is the least significant (M = 2.76), consistent with limited emphasis on formal hierarchy. Generations X and Y assign greater importance to Authority (M = 3.82), reflecting the balance between emerging individualism and recognition of traditional sources of influence. Generation Z ranks Authority the highest (M = 4.27), likely reflecting the influence of opinion leaders on social media and the role of perceived authority figures in navigating an unstable social environment.

The **Hedonism value,** representing personal pleasure and self-realization, gradually increases across generations. It is least significant for Baby Boomers and Generation X, reflecting a stronger orientation toward work and stability. For Generations Y and Z, Hedonism is more highly rated, reaching M = 4.66 in Generation Z, reflecting an emphasis on personal satisfaction, positive experiences, and the influence of social media.

The **Tradition value**, represented by items such as religious devotion, is least pronounced among Baby Boomers and Generation Y, reflecting a trend among younger generations toward religious neutrality and a move away from traditional religious norms.

The **Stimulation value**, reflecting a preference for novelty, variety, and risk-taking, is among the least prioritized across all generations. It is lowest for Baby Boomers (M = 3.56) but increases steadily to Generation Z (M = 4.72), indicating greater openness to change and willingness to engage with new opportunities.

Comparisons between Baby Boomers (born 1944–1963) and Generation X (born 1964–1984) show largely similar **value priorities**, with both cohorts emphasizing stability, family responsibility, and work ethics. Generation X, despite experiencing economic and social transformations, retains a value orientation close to that of Baby Boomers, particularly in the **Conservation** dimension.

Generations Y (born 1985–2003) and Z (born after 2003) share similar value profiles characterized by **autonomy, innovation, personal development, and creativity.** This similarity can be attributed to socialization in environments marked by rapid technological progress and high social mobility.

Significant intergenerational differences are observed when comparing Baby Boomers with Generations Y and Z. These differences appear in the **motivational value types** of Self-Direction, Stimulation, Hedonism, Achievement, Power, Conformity, and Tradition. Generations Y and Z are more oriented toward personal freedom, self-expression, and pleasure, whereas Baby Boomers emphasize stability and adherence to traditional social norms. Differences between Generation X and Generation Z in Stimulation, Achievement, and Power reflect historical and social transformations: Generation X emphasizes long-term stability and rule-following, whereas Generation Z is oriented toward flexible achievement strategies, openness to new opportunities, and views Power as a means of influence, including via digital channels and social entrepreneurship.

Across all generations, **Benevolence, Universalism, and Security** remain highly prioritized. These values support personal and family well-being, social tolerance, and care for the environment, confirming their universal importance. Values associated with **Openness to Change** generally decrease with age, whereas **Conservation values** tend to strengthen [13].

Conclusion.

1. **Baby Boomers and Generation X** exhibit largely similar value structures, emphasizing **stability, tradition, work ethic, and social responsibility**. In contrast, **Generations Y and Z** share value orientations focused on **individualism, self-realization, creativity, and innovation**. These patterns reflect the historical, technological, and socio-cultural contexts shaping each cohort, as well as shared socialization conditions.

2. **Comparisons between Baby Boomers and Generation Y** show significant differences in the **motivational value types** of **Self-Direction, Stimulation, Hedonism, Achievement, and Power.** Younger individuals prioritize **personal freedom, self-expression, and pleasure**, whereas Baby Boomers emphasize **stability, tradition, and social responsibility.**

3. **Comparisons between Baby Boomers and Generation Z** reveal differences in **Conformity, Tradition, Stimulation, Hedonism, Achievement, and Power.** Generation Z is oriented toward **individuality, personal growth, creativity, and flexibility**, while Baby Boomers maintain **conservation-oriented values**, emphasizing social norms and stability.

4. **Differences between Generation X and Generation Z** are observed in **Stimulation, Achievement, and Power**. Generation Z interprets Achievement as a **dynamic and flexible process** and views Power as a means of **influence and social change,** including via digital and social media channels. Generation X, by contrast, is oriented toward **long-term stability and traditional hierarchical structures.**

5. **Across all generations**, the values of **Benevolence, Universalism, and Security** remain highly prioritized. These values reflect concern for **family, close others, social tolerance, and the natural environment. Conservation values** tend to strengthen with age, whereas **Openness to Change values** generally decrease.

6. **Generation Z** is characterized by pronounced **individualism** and strong orientation toward **Self-expression, Hedonism, and Achievement**. Values associated with **pleasure and enjoyment of life** are particularly significant, reflecting the influence of **digitalization, globalization, and social media**. At the same time, respect for elders persists, demonstrating the continuity of **family and cultural norms.**

7. Generation Z demonstrates transformations in attitudes toward **family and marriage,** including delayed marriage and adoption of **alternative family forms,** while retaining the importance of family values. Socio-economic and cultural changes contribute to the **dominance of individual values among youth,** a **decline in the authority of older generations**, and **increased intergenerational distance.** Nevertheless, universal values such as **Security, Benevolence, and concern for others** ensure the **preservation of intergenerational continuity.**

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TECHNICAL SCIENCES

APPROACHES TO BUILDING FAULT-TOLERANT DATA TRANSMISSION CHANNELS IN HIGH-LOAD SYSTEMS

Berezhnoy A.
Bachelor's degree,
Peter the Great St. Petersburg Polytechnic University
https://orcid.org/0009-0001-7615-4204
DOI: 10.5281/zenodo.18738536

Abstract
This article analyzes approaches to building fault-tolerant data transmission channels in high-load distributed systems. It examines key requirements for communication infrastructure and considers common risks associated with single points of failure, channel congestion, and network node failures. Special attention is given to redundancy schemes, routing mechanisms, and load balancing techniques. The study analyzes active–active and active–standby configurations, N+1 redundancy models, multipath routing methods, dynamic failover techniques, and flow-control mechanisms. It also describes principles of architecture design and traffic profiling, as well as methods of modeling and load testing.
Keywords: fault tolerance, data transmission channels, Service Level Agreement (SLA), redundancy, load balancing, routing, high-load systems.

Introduction

The rapid development of digital infrastructure and the widespread adoption of distributed computing platforms have significantly increased the reliability requirements for communication subsystems. As the number of services, the volume of transmitted data, and the intensity of user traffic continue to grow, communication channels become a key element determining the resilience of the entire system under high load conditions. In the design of modern distributed solutions, particular attention is paid to the ability of the network infrastructure to ensure continuous data exchange under variable load and during interactions between heterogeneous components, including mobile, cloud, and edge nodes.

However, the rising level of complexity in the system makes network congestion risks and the inconsistencies in the routing of traffic even more pronounced. The conventional models of network architecture characterized by static network topology and network capacity are inadequate to provide the desired level of network availability. This leads to the need for the incorporation of fault tolerance and intelligent load management in the routing of traffic. The aim of this study is to examine approaches to building fault-tolerant data transmission channels in high-load distributed systems.

Main part. Requirements for fault-tolerant data transmission channels in distributed systems

The reliability of data transmission channels directly affects service availability. Even if individual nodes remain operational, a failure at the network level may render a distributed application unavailable. Modern distributed architectures assume that the network cannot be considered fully reliable, therefore, the system must be tolerant to network faults. A classic formulation of the “inherent unreliability of the network” principle states that no distributed system is immune to communication failures, which implies the need to incorporate strategies for network partition scenarios at the design stage [1].

To formalize the quality requirements for data transmission channels in high-load systems, Service Level Agreement (SLA) metrics are commonly used. The key indicators include service availability, response time (latency), packet loss rate, and channel throughput. Availability is frequently defined as the proportion of time during which the system functions correctly. It is typically expressed as a percentage or as the number of nines. High-load systems often aim for four or five nines of availability and it necessitates specialized redundancy mechanisms and fast recovery procedures in the event of failures (table 1).

Table 1.

Maximum allowable downtime for different availability levels [2]

Years of continuous operations	1	2	3
Availability	Maximum allowable downtime		
99.0000% (2-9s)	3 d 15 h 36 min 0 s	7 d 7 h 12 min 0 s	10 d 22 h 48 min 0 s
99.9000% (3-9s)	8 h 45 min 15 s	17 h 31 min 12 s	1 d 2 h 16 min 48 s
99.9900% (4-9s)	52 min 34 s	1 h 45 min 7 s	2 h 37 min 41 s
99.9990% (5-9s)	5 min 15 s	10 min 31 s	15 min 46 s
99.9999% (6-9s)	32 s ± 1 min 3 s	1 min 3 s	1 min 35 s

In addition to availability, SLA typically specify parameters related to data transmission latency. Another important metric that describes how much data or requests the system can handle in a given amount of time is channel throughput. Lastly, since data loss on a communication channel result in retransmissions and longer delays, packet or request loss is also important.

To ensure fault tolerance, it is necessary to analyze which failures are most probable and most critical in a high-load distributed system. Typical causes of failures can be divided into several categories. **Node failure (server/component)** refers to the malfunction of a computing node due to software errors, hardware failure, or overload. In a distributed system, the failure of a single node should not paralyze the entire system.

A channel/network device failure corresponds to a broken network connection and can be related to switch failure, router failure, and failure of other related devices like the network interface card. Network-related failures generally tend to have wider-reaching consequences than other types of failures since several services can potentially stop simultaneously due to events like a downed backbone connection.

Network congestion arises when traffic exceeds channel capacity or router capacity. It leads to queue formation in buffers, latency, and packet loss. Bottlenecks occur at different layers such as constrained WAN links connecting data centers and congested load balancers.

It is feasible to develop general specifications for communication channels in a high-load system by considering all of these risks. High availability for channels necessitates the existence of redundant routes and reduced downtime during failures. Under typical operating conditions, they must guarantee minimal latency and almost no packet loss.

Technologies for redundancy, routing, and load balancing

The primary method for increasing the fault tolerance of communication channels is **redundancy,** which involves introducing additional resources (channels, nodes, devices) capable of taking over operations when a primary component fails. Several common redundancy schemes are widely used.

Active–Active configuration involves two or more nodes (or communication channels) operating in parallel under load. All nodes in the cluster are active simultaneously and process traffic, typically with load balancing mechanisms distributing requests among them. The advantage of the Active–Active approach is that it provides not only fault tolerance but also increased overall system performance.

Active–Standby configuration entails one node operating as the active component while another remains in a hot or warm standby state and not processing traffic until the primary node fails. The standby node is configured similarly to the primary one and continuously synchronizes with it. Upon detection of a failure in the primary node, the standby node becomes active and assumes its functions.

N+1 redundancy generalizes the idea of active redundancy: for every N operational components, one additional spare component is added. This allows the system to withstand the failure of any one of the N components without loss of functionality [3]. The spare component may operate in a passive mode or may dynamically share the load, for example, by processing a portion of the traffic while simultaneously serving as a backup.

It should be noted that introducing redundancy also requires **the design of failure detection** and **switchover mechanisms**. In Active–Active configurations, coordination protocols are typically employed, whereas Active–Standby systems rely on heartbeat connections and leader election algorithms. The objective is to minimize the time between a failure event and full service restoration. In modern networks, automatic switchover times may be on the order of tens of milliseconds. For example, Fast ReRoute (FRR) technologies can locally redirect traffic to a preconfigured backup path in approximately 20-50 ms without waiting for global route recalculation (fig. 1).

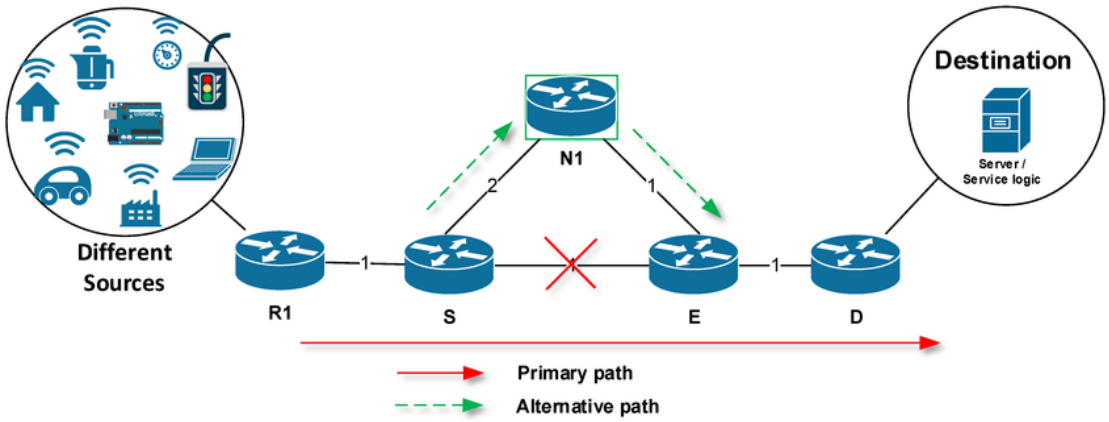

Figure 1. The principle of FRR [4]

In addition to redundancy of individual devices and channels, an essential means of ensuring reliable data transmission is intelligent routing capable of bypassing problematic segments of the network. In traditional networks, a router or link failure could interrupt communication for the duration of route recalculation.

The simultaneous use of several independent paths for data transmission between nodes is known as multipath routing. The fundamental idea is that traffic is automatically rerouted through a different channel if one path fails or deteriorates. The ECMP (Equal-Cost Multi-Path) protocol in IP networks, which divides

packets among multiple equivalent routes, is one illustration. Multipath Transmission Control Protocol (TCP) allows a single TCP connection to distribute segments across several network interfaces at a higher level (fig. 2).

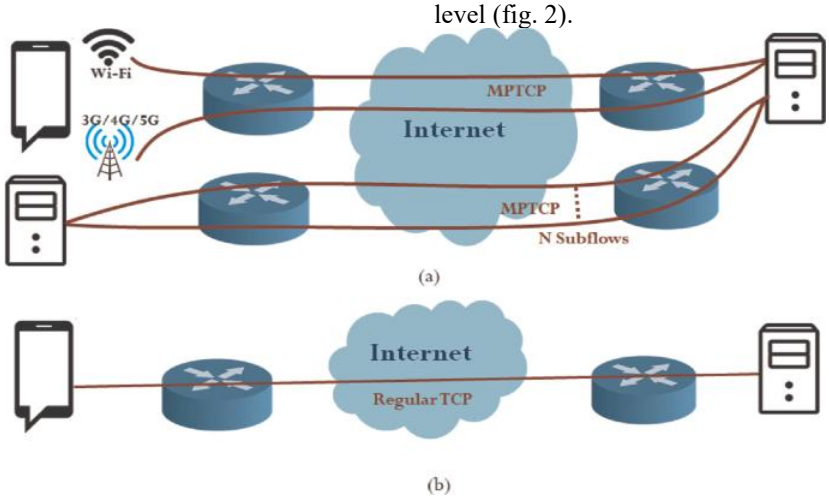

Figure 2. (a) Multipath TCP connection (b) Regular TCP connection scenarios [5]

Quality-aware and congestion-aware routing represent another aspect of resilience. A network may proactively change the traffic path if problems such as high latency or packet loss are observed on the current route. This concept is implemented, for instance, in SD-WAN solutions, where devices continuously monitor multiple available WAN channels and switch critical traffic to the optimal one when degradation occurs on a particular channel. Heterogeneous routing also deserves mention, this occurs when alternative channels use different physical media. This approach enhances resilience to external factors.

Load balancing is a considerable part of fault tolerance in high-load computing. It helps distribute the incoming traffic across various servers/channels so that no server becomes overloaded. This commonly improves performance as well as fault tolerance. There are different methods of doing this, which mostly depend upon the OSI layers being used.

Layer 4 (transport-layer) load balancing involves making routing decisions based on transport-protocol information such as IP addresses, ports, and protocol types (TCP/UDP). These balancers do not inspect traffic beyond transport-layer headers. This provides advantages in speed and efficiency: an L4 load balancer can redirect packets very quickly without examining their payload and often without terminating the connection [6].

Layer 7, or application-layer, load balancing operates as a full proxy, terminating the incoming connection and analyzing the contents of the request before selecting a backend node. An L7 balancer can terminate SSL/TLS, decrypt traffic, perform inspection, and make intelligent routing decisions based on application-level logic.

In addition to this method, **queues and backpressure mechanisms** holds one of the main places in flow control. Under overload conditions, small queues can smooth short-term spikes in incoming requests. However, large queues increase response times and may worsen overall performance during sustained overload.

Taken together, these measures provide the system to degrade gracefully rather than collapse entirely under paramount load. It can be advantageous for a web service under stress to slow down responses or temporarily disable non-critical functionality rather than become completely unresponsive. Proper flow-control mechanisms enable such behavior, helping maintain SLA compliance at the “best effort under failure” level even during emergency conditions.

Approaches to designing and evaluating communication solutions

Designing a system that can handle large volumes of traffic and be fault tolerant must begin with a clear understanding of the requirements of the SLA and traffic profiles. The levels of availability and performance requirements and the workloads at which the system will be run must be clearly understood. This sets the architecture baseline.

The first principle is **designing without a single point of failure**. Any component whose failure would violate the SLA must either be redundant or removed from the critical execution path. In practice, this involves incorporating redundancy at all levels: multiple application servers behind a load balancer, replicated databases, duplicated network channels, backup power sources, and so on. The “no SPOF (Single Point of Failure)” principle is a cornerstone of high-availability design [7]. Even if a component is highly reliable, it still depends on other elements (hardware, operating systems, network), any of which may fail (fig. 3)

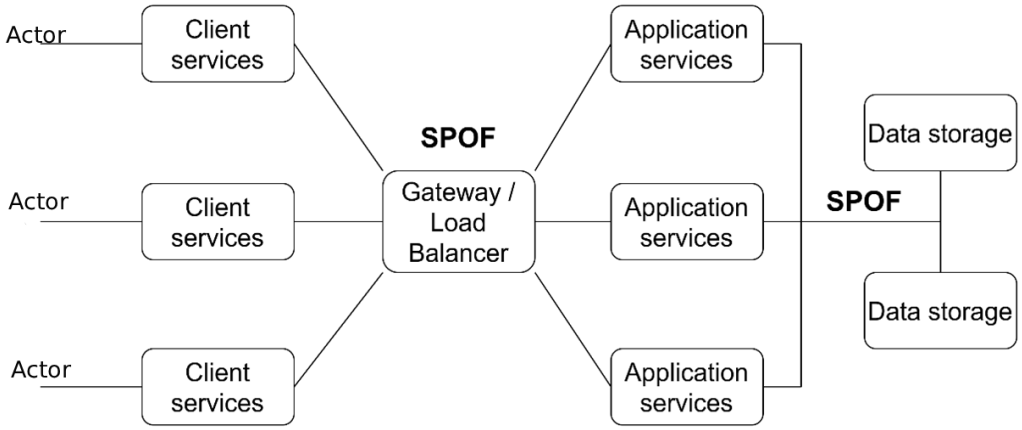

Figure 3. System architecture with SPOF

The second principle is **ensuring that system capacity matches the traffic profile with sufficient margin.** The designer must account for both the nominal load (average load) and the peak load, provisioning adequate channel throughput and node performance. Capacity planning, modeling operational workloads and estimating the required number of resources, is strongly recommended. A common guideline is that the system should sustain the peak load even in the event of failure of one of the N replicas.

Consideration of traffic characteristics and data patterns can be identified as the third principle. If traffic is uneven in daily peaks or seasonal surges, the system must either scale accordingly or be initially designed for the worst-case scenario. If different traffic types are present, they should be separated and prioritized so that background tasks do not affect user-facing operations.

Another principle is **fail-fast and graceful degradation**. System behavior under adverse conditions must be explicitly considered during design. A system should detect failures quickly and either switch to a backup resource immediately or degrade gracefully. Graceful degradation is an important property: rather than failing completely, a service may reduce quality (disable certain features, slow down, or present a fallback response).

The final principle is **simplicity and observability**. Complex fault-tolerance mechanisms (such as fully active-active clusters with replication) must be justified by SLA requirements. In some cases, a simpler redundancy scheme may be preferable for maintainability if it still meets the performance and availability targets.

After the architecture has been designed, it is necessary to verify that it can withstand the declared loads and failure scenarios. This is achieved through modeling, simulation, and load testing [8]. During the design stage, mathematical reliability models are often used to estimate the probability of failure-free operation based on component reliability and redundancy schemes. Load testing is a practical method for ensuring that communication channels can sustain the required traffic volume and that appropriate mechanisms activate under overload conditions.

Ultimately, the combination of preliminary modeling and practical stress testing provides confidence that the designed communication infrastructure truly meets the requirements. An important final step is correlating the obtained results with the original objectives.

Conclusion

Modern distributed information systems operate in an environment characterized by highly dynamic traffic patterns, a wide variety of communication technologies, and increasingly complex network infrastructures. The growth in data volumes, the rising number of users, and the expansion of geographically distributed services create additional load on data transmission channels, which necessitates particular attention to their reliability and resilience.

A major and one of the main aspects of designing the communication subsystem is the ability of the network to remain operational in the presence of partial failures or routing inconsistencies. Achieving this capability requires the use of various architectural approaches, including resource redundancy, alternative transmission paths, load balancing, and adaptive traffic management mechanisms. The development of such solutions put specialists in need of careful consideration of network characteristics and service availability requirements.

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AUTOMATED DETECTION OF SWAHILI SCAM MESSAGES IN TANZANIA USING NATURAL LANGUAGE PROCESSING AND MACHINE LEARNING MODELS

Gaudance Stanslaus Tesha
Dar es Salaam Institute of Technology, P.O. Box 2958, Dar es Salaam, Tanzania
https://orcid.org/0000-0002-4905-7951
DOI: 10.5281/zenodo.18738549

Abstract
In recent years, cybersecurity threats have become increasingly prevalent worldwide, with scam messages especially those delivered via text and online platforms emerging as a major concern. These messages aim to trick recipients into disclosing personal or financial information, leading to identity theft, privacy infringements, and financial loss. In Tanzania, the rapid growth of mobile communication technologies and mobile money services has intensified this threat. Kiswahili, being the dominant language in digital communication, adds a unique dimension to the problem. This study develops Natural Language Processing (NLP)-driven Machine Learning (ML) models to detect scam messages written in Kiswahili. A labeled dataset was constructed and models such as Support Vector Machine (SVM), Random Forest (RF), Bi-LSTM, and Swahili-BERT were evaluated. Results indicate that Swahili-BERT achieved the highest detection accuracy. The study highlights the importance of context-aware, language-specific NLP tools and recommends real-time, user-friendly, and privacy-compliant deployment strategies.

Keywords: Cybersecurity, Scam Detection, Kiswahili NLP, Machine Learning, Swahili-BERT, Mobile Money Fraud, Low-Resource Languages.

1.1 Background of the Study

Cybersecurity has become an essential pillar in protecting digital communication systems from evolving threats such as scam messages, phishing attacks, and data breaches. Scam messages designed to deceive individuals into revealing sensitive information pose significant risks to personal privacy and financial security. Traditional detection approaches, such as rule-based systems, face limitations in scalability and adaptability. Advances in NLP and ML offer promising alternatives by enabling automated detection of scam content through linguistic and contextual analysis.

In Tanzania, mobile money platforms dominate financial transactions, and Kiswahili is the most widely used language in digital communication. This creates a unique context where scam detection systems tailored to Kiswahili are urgently needed. While English-language scam detection research is advanced, Kiswahili remains underrepresented as a low-resource language in NLP.

1.2 Problem Statement

Despite the increasing prevalence of scam messages in Tanzania, there remains a lack of automated detection systems specifically designed for Kiswahili. Most existing models are optimized for English and fail to account for the linguistic nuances of Kiswahili scam messages, leaving millions of mobile money users vulnerable to fraud. The absence of annotated datasets and specialized NLP tools for Kiswahili further constrains system development.

1.3 Significance of the Study

This research enhances cybersecurity for Swahili speakers, informs policy and regulation, empowers telecom and financial service providers, advances NLP research in low-resource languages, and contributes practical tools for detecting fraudulent messages.

1.4 Scope of the Study

The study focuses on scam messages written in Kiswahili, transmitted via SMS and mobile platforms. It excludes voice-based or image-based scams.

2 Literature Review

2.1 Introduction

Scam detection through NLP and ML has been extensively studied for English and other high resource languages. However, Kiswahili presents unique challenges due to lack of annotated datasets, informal language usage, and morphological complexity.

2.2 Existing Research Insights

i. **Scam Detection Using NLP and ML**: Supervised classifiers such as SVM, Random Forest, and deep learning models outperform traditional rule-based systems.

ii. **Maritime Cybersecurity**: Highlights hybrid threats and gaps in governance.

iii. **Detection and Response Time**: Real-time detection is crucial but computationally intensive.

iv. **IoT Security**: Phishing and scams exploit IoT vulnerabilities.

2.3 Challenges in Kiswahili NLP

i. Limited annotated datasets.
ii. Lack of pre-trained Swahili NLP models.
iii. Code-switching and slang.
iv. Morphological complexity.

2.4 Theoretical Framework

i. **Information Processing Theory**: Scam messages exploit cognitive biases.

ii. **Communication Theory**: Explains persuasive manipulation in scam texts.

iii. **Supervised Learning Theory**: Underpins the ML modeling process.

3 Methodology

The methodology involved:

i. **Data Collection**: Gathering real-world Kiswahili scam messages.

ii. **Data Annotation**: Labeling messages as genuine or fraudulent.

iii. **Preprocessing**: Normalization, stop-word removal, and tokenization.

iv. **Model Development**: Implementing SVM, RF, Bi-LSTM, and Swahili-BERT.

v. **Evaluation**: Using accuracy, precision, recall, and F1-score.

3.1 Dataset

The dataset used in this study was designed to capture the unique linguistic and contextual features of scam communication in Kiswahili. Data was collected from multiple sources to ensure diversity and reliability. Specifically, three main sources were utilized:

i. **Publicly Available Samples** – Existing Kiswahili SMS datasets and online repositories containing examples of fraudulent and non-fraudulent mobile messages.

ii. **Law Enforcement Collaboration** – Anonymized scam messages obtained in partnership with the Tanzania Police Force's cybercrime unit, which provided authentic cases of mobile money fraud, phishing attempts, and other digital scams.

iii. **User-Contributed Data** – Data collected through structured questionnaires and community surveys, where participants shared real-life scam messages they had received.

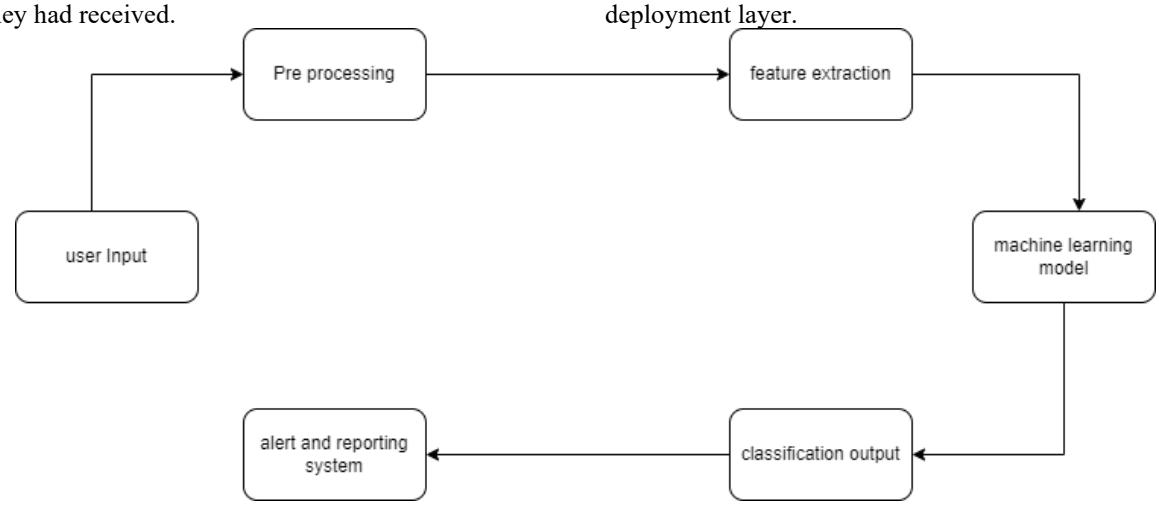
In total, the dataset consisted of approximately *5000* messages of which around *60%* were scam-related and *40%* were legitimate. Each message was manually annotated by Swahili language experts and cybersecurity practitioners to ensure accuracy. Annotation involved labeling messages as **Scam** or **Not Scam**, and further classifying scam messages into categories such as mobile money fraud, fake promotions, lottery scams, and phishing.

This structured dataset was then pre-processed, tokenized, and fed into the Swahili-BERT model for training and evaluation. By focusing on locally relevant messages, the dataset addressed the scarcity of Kiswahili resources in Natural Language Processing (NLP), thereby strengthening the system's applicability to Tanzania's cybersecurity landscape.

System Architecture & Backend

4.1 System Architecture

The architecture consists of a data preprocessing module, feature extraction engine, ML classifier, and deployment layer.



1. User Input

Input Type: SMS or Text Message

The system initiates its operation by receiving a text message sent by a user. This message serves as the primary input and may contain various content in Swahili. The message is captured by the system through a designated interface, such as an SMS gateway or a mobile application.

2. Text Preprocessing Steps:

i). Tokenization: The input text is segmented into individual tokens (words or terms) to enable easier analysis in subsequent stages.

ii). Stopword Removal: Commonly occurring but semantically insignificant words (e.g., "na", "ya", "kwa") are removed from the tokenized list to reduce noise and improve the focus on meaningful content.

iii). Lemmatization: Each word is reduced to its base or dictionary form (lemma). For example, Swahili words like "kupokea" might be lemmatized to "pokea." This step standardizes word forms, enhancing the accuracy of feature representation.

The preprocessing stage transforms raw, unstructured text into a cleaner and more uniform format. This ensures that the input is suitable for feature extraction and reduces variability due to linguistic variations in the Swahili language.

3. Feature Extraction Techniques:

i). TF-IDF (Term Frequency–Inverse Document Frequency): This statistical measure evaluates how important a word is to a message relative to a larger corpus. It helps highlight keywords that are likely to indicate scam messages.

ii). Word Embeddings (e.g., Word2Vec, GloVe): Words are represented as dense vectors in a continuous vector space, capturing semantic relationships between words. This allows the system to understand context and similarity between terms even if they are not identical.

At this stage, the preprocessed text is transformed into a structured numerical format that can be understood by the machine learning model. This representation preserves the semantic and statistical features of the message content, enabling more accurate classification.

4. Machine Learning Model

i). Input: Numerical feature vectors obtained from the Feature Extraction step

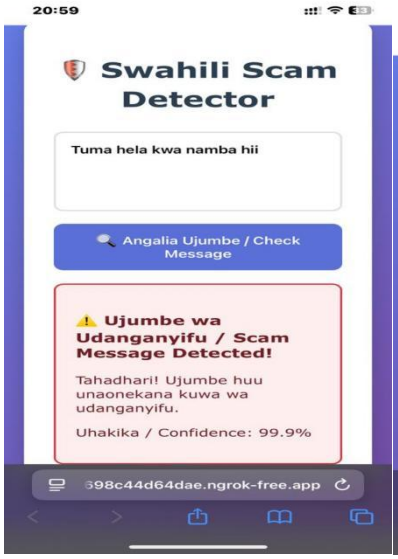
ii). Model Type: Supervised learning model trained on a labeled dataset of Swahili scam and non-scam messages

The core of the system is a machine learning classifier that analyzes the extracted features. It has been

trained on historical SMS data, where each message is labeled as either “Scam” or “Non-Scam.” Using this knowledge, the model predicts the label of incoming messages based on patterns it has learned.

5. Classification Possible Output

i). Scam

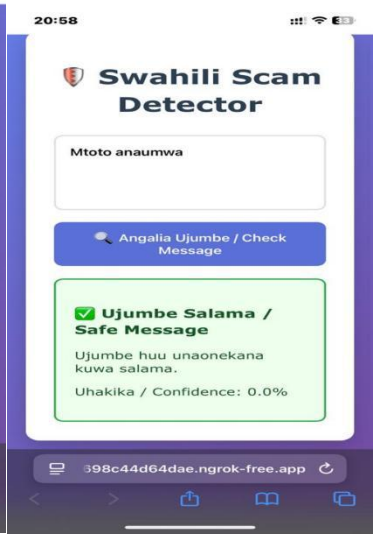

20:59
Swahili Scam Detector
Tuma hela kwa namba hii
Angalia Ujumbe / Check Message
Ujumbe wa Udanganyifu / Scam Message Detected!
Tahadhari! Ujumbe huu unaonekana kuwa wa udanganyifu.
Uhakika / Confidence: 99.9%
398c44d64dae.ngrok-free.app

i). User Notification: If a message is classified as a scam, the system may display a warning notification to the user, cautioning them against interacting with the content.

ii). Message Blocking: In cases where automatic protection is enabled, the system can prevent the message from reaching the user's inbox or take other security measures, such as reporting the sender.

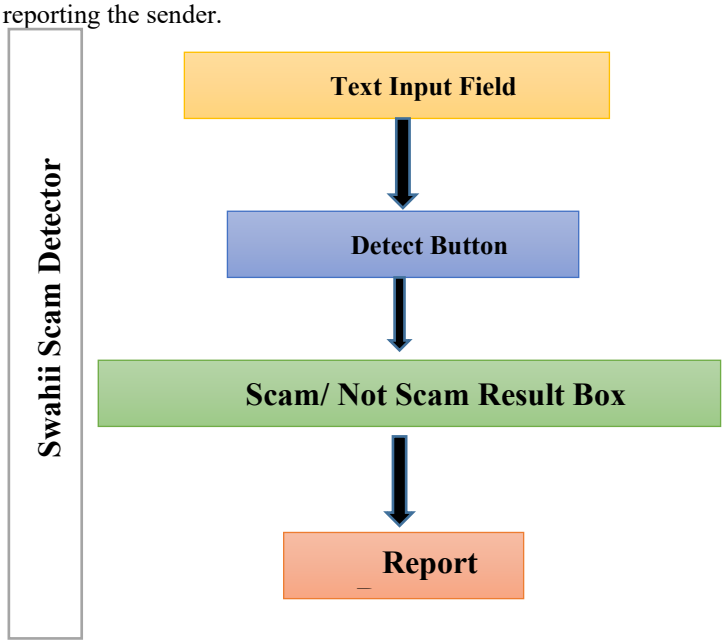
ii). Non-Scam

The machine learning model outputs a classification label that indicates whether the incoming message is potentially fraudulent ("Scam") or safe ("Non-Scam"). This result forms the basis for subsequent action or alert.



This optional module enhances user safety by taking proactive steps when a scam is detected. It adds a protective layer to the classification system, helping mitigate risks associated with SMS fraud and social engineering attacks.

The flow chart of the system is



4.2 Backend System Code (Flask API)

A Flask-based API was implemented to enable integration with SMS platforms and mobile apps. It handles incoming messages, preprocesses text, applies the trained ML model, and returns classification results.

Results and Discussion

i. **Swahili-BERT** achieved the highest detection accuracy compared to other models.

ii. Scam messages commonly exhibited urgency, requests for personal info, and poor grammar.

iii. Stakeholders emphasized real-time, user-friendly, and privacy-compliant deployment.

Deployment Strategy

The model can be integrated with Tanzania Police Force systems, telecom providers, and financial institutions to automatically filter scam messages. Deployment considerations include scalability, API integration, and user accessibility.

Security & Privacy Considerations

i. **Data Privacy**: Ensuring user information is anonymized.

ii. **System Security**: Protecting the model API from misuse.

iii. **Compliance**: Adhering to Tanzanian cybersecurity regulations.

8.1 Summary Discussion

This study set out to develop **NLP-driven machine learning models** capable of detecting scam messages written in Kiswahili. To achieve this, the research investigated linguistic patterns within scam texts, constructed a labeled dataset, and trained multiple models **Support Vector Machines (SVM), Random Forest, Bi-LSTM, and Swahili-BERT** which were evaluated using standard performance metrics.

The study also examined the perceptions and expectations of key stakeholders in Tanzania, particularly the **Tanzania Police Force**.

8.2 Study Conclusion

NLP-integrated ML models, particularly transformer-based ones, are effective for Kiswahili scam detection. However, more Swahili-specific resources are needed.

8.3 Recommendations for future study

i. Expand the annotated dataset.
ii. Develop more Swahili NLP tools.
iii. Deploy models in real-time systems.
iv. Conduct awareness training for end-users.

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АНАЛІЗ МОЖЛИВОСТЕЙ СТВОРЕННЯ БЕЗРЕДУКТОРНИХ БУРОШНЕКОВИХ МОБІЛЬНИХ ГІДРОПРИВОДІВ

Аврунін Г.А.
кандидат технічних наук,
Нікітін С.А.
аспірант,
Мороз І.І.
старший викладач,
Харківський національний автомобільно-дорожній університет
Цента Є.М.
кандидат технічних наук,
Національний технічний університет «Харківський політехнічний інститут»

ANALYSIS OF THE POSSIBILITIES OF CREATING GEARLESS MOBILE DRILLING AUG HYDRAULIC DRIVES

Avrunin G.
Candidate of Technical Sciences,
Nikitin S.
Postgraduate Student,
Moroz I.
Senior Lecturer,
Kharkiv National Automobile and Highway University
Tsenta Y.
Candidate of Technical Sciences
National technical university «Kharkiv Politechnik Institute», Ukraine
DOI: 10.5281/zenodo.18738564

Анотація

Мобільні бурильно-шнекові машини застосовують механічні приводи або гідроприводи з героторними гідромоторами і редукторами. На основі огляду технічних характеристик сучасних високомоментних радіальнопоршневих гідромоторів зроблений висновок щодо можливості їх застосування в якості безредукторних приводів обертання шнеків бурильних машин. Проведений аналіз конструкцій високомоментних гідромоторів представляється корисним для фахівців в галузі об'ємних гідроприводів і студентів-магістрів.

Abstract

Mobile drilling auger machines use mechanical drives or hydraulic drives with gerotor hydraulic motors and gearboxes. Based on a review of the technical characteristics of modern high-torque radial piston hydraulic motors, a conclusion was made regarding the possibility of their use as gearless drives for rotating augers useful for specialists in the field of volumetric hydraulic drives and master's students.

Ключові слова: Мобільний бурошнековий гідропривод, героторний гідромотор, планетарний редуктор, високомоментні радіальнопоршневі гідромотори, крутний момент, витрата робочої рідини.

Keywords: Mobile auger hydraulic drive, gerotor hydraulic motor, planetary gearbox, high-torque radial piston hydraulic motors, torque, working fluid consumption.

Вступ

Мобільні машини для виконання бурильних робіт широко застосовуються в різних галузях промисловості, зокрема для будівництва споруд різного призначення. Наприклад, в вітчизняний практиці такі машини мають назву бурильно-кранових машин моделі БКМ, які створені на базі колісних тракторів. Однак ці машини мають обмежені можливості щодо крутного моменту і в деяких випадках не задовольняють вимоги споживачів. Аналіз сучасних досягнень показує на суттєво вищі параметри щодо крутних моментів і діаметрів шурфів бурильних машин закордонних виробників. В якості приводної частини для обертання шнеків здійснився перехід з механічних трансмісій на об'ємні гідроприводи з використанням шестеренних героторних гідромоторів і планетарних редукторів. В той же час огляд номенклатури високомоментних радіальнопоршневих гідромоторів показує на такі досягнуті значення крутного моменту, які б дали можливість створювати безредукторні приводи бурильних машин. С точки зору реалізації такого переходу здається важливим провести порівняльний аналіз редукторних і безредукторних гідроприводів бурильних машин.

Огляд літератури

Основними виробниками бурильно-кранових машин в в Україні є компанії «Будагромаш» [1; 2], «Flagma» [3; 4], «Гідролідер» [5] і «СпецТехСервіс-ІВК» [6], які монтують технологічне обладнання га колісних тракторах ХТЗ-150К , ХТЗ-17221 і ХТА-200. Машини з шифрами БКМ і БКУ обладнані механічним або гідравлічним приводами обертання

буру. При застосуванні гідроприводів використовують аксіальнопоршневі гідромотори з редукторами. Крім бурового та кранового обладнання машини можуть оснащатися бульдозерним відвалом, що підвищує їх універсальність. Крутний момент на шнеках досягає 8000 Н.м, а частота обертання від 60 хв$^{-1}$ до 120 хв$^{-1}$.

За кордоном випускаються комплектні бурошнекові приводи, які створені в моноблоковому виконанні і складаються з героторного гідромотора, планетарного редуктора та механічного вузла для закріплення на стрілі бурильної установки. Широке застосування в якості спеціалізованих бурошнекових приводів для роботи на тракторах і екскаваторах знайшли вироби фірм «Belltec» (США) [7], «Digga» (Австралія) [8] і «Rayattachments» (Китай) [9], яка має найбільший за крутним моментом бур в 100 кН.м.

Фірма «Belltec» має типорозмірний ряд з 6-ти шнекових приводів в діапазоні крутних моментів від 3381 Н.м до 16614 Н.м і максимальною частотою обертання від 86 хв$^{-1}$ до 26 хв$^{-1}$. Максимальна потужність приводів від 30 кВт до 45 кВт, маса від 72 кг до 136 кг. Кріплення шнеків «Belltec» доступні для міні-навантажувачів, тракторних фронтальних навантажувачів і екскаваторів.

Компанія «Digga-Центральна Європа» призводить гідравлічні бурильні приводи на базі героторних гідромоторів і редукторів з крутними моментами від 1171 Н.м (DIGGA PDD) до 38420 Н.м (DIGGA PD 50) і потужністю в 25 кВт або 50 кВт. До номенклатурного ряду приводів входять 18 типорозмірів (моделей) масою від 41 кг до 300 кг. В технічних характеристиках приводів наведені обмеження щодо максимальної механічної потужності, а також максимальних значень тиску і витрати в гідроприводі. Наприклад, в приводі PD10 механічна потужність обмежена значенням 25 кВт, для максимального тиску в 24 МПа витрата не повинна перевищувати 60 л/хв, а при максимальній витраті в 115 л/хв тиск не повинен перевищувати 13 МПа. Множення значень тиску на витрату дає параметр гідравлічної потужності і при обмеженні за тиском значення гідравлічної потужності дорівнює 24 кВт, а при обмеженні за витратою маємо значення в 24,9 кВт. Практично ці гідравлічні обмеження співпадають з обмеженням механічної потужності в 25 кВт. Для контролю за потужністю привода шнекового буру досить зручно вимірювати тиск в гідроприводі і частоту обертання гідромотора, тобто його теоретичну витрату.

Серед мобільних бурошнекових гідроприводів найбільшими щодо крутного моменту є приводи моделі «REA» (RAY) . Типорозмірний ряд приводів складається моделей від REA2000 до REA100000 з крутним моментом від 1871 Н.м до 103509 Н.м з частотою обертання 26…45 хв$^{-1}$ до 5…13 хв$^{-1}$ на тиск від 21 МПа до 35 МПа і витрату робочої рідини від 23 л/хв…53 л/хв до 100 л/хв…280 л/хв. Маса приводів від 54 кг до 1350 кг. Довжина блоків від 595 мм до 1450 мм, діаметр блоків від 200 мм до 675 мм. Рекомендований діаметр застосування шнеків від 400 мм до 1800 мм. Також фірма дає рекомендації щодо мас машин, на які можливо встановлювати бурильне обладнання, тобто від 1т до 50т. Компанія «Changzhou Raymond Precision Machinery Co, Itd» з виробництва спеціалізованого робочого обладнання для встановлення на трактори та екскаватори заснована в 2002 році. В номенклатурі виробництва є професійне навісне обладнання, наприклад земляний бур, швидкоз'єднувальний пристрій, гідравлічні молот та грейфер. Компания «Changzhou Raymond International Trading Co., Ltd» є дочірньою компанією «Imp. & Exp. Платформа». Назва «RAY Attachments» відноситься до китайського бренду.

Таким чином, закордонні мобільні бурильні машин мають суттєву перевагу перед вітчизняними за крутним моментом. В основі цих приводів лежить об'ємний гідропривод з героторним гідромотором і планетарний редуктор для підвищення крутного моменту. В той же час огляд номенклатури сучасних гідроприводів вказує на наявність високомоментних гідромоторів з достатньо високими значеннями крутних моментів. Застосування високомоментних гідромоторів дає можливість відмовитися від редуктора, що скорочує шлях створення бурильних машин. За нашими даними конструкторські і дослідницькі роботи щодо створення безредукторних приводів з високомоментними гідромоторами як альтернатива редукторним гідроприводам до останнього часу не проводилася. Тому в статті зроблений перший крок в цьому напрямку, а саме спроба проаналізувати можливість застосування високомоментного гідромотора в самому найбільшому за крутним моментом бурильному приводі в 100 кН.м і дати порівняльну оцінку розглянутим гідроприводам.

Основна частина

Розглянемо більш ретельно технічні характеристики шнекових приводів «REA». Щодо можливостей застосування, то шнекові приводи моделей від REA2000 до REA4500 призначені для тракторів і екскаваторів масою від 1 т до 5 т (рис. 1); моделей від REA5000 до REA8000 підходять для екскаваторів масою від 4,5 т до 12 т, а шнекові приводи від моделі REA50000 до REA65000 використовують для екскаваторів масою від 20 т до 50 т.

Рис. 1. Шнекові приводи «REA» для екскаваторів масою від 1 до 5 т

В шнекових приводах використовуються героторні гідромотори фірм «Danfoss» або «Parker» в комбінації з планетарними редукторами і пропонується 36-місячна гарантія для захисту всієї приводної головки. Основними перевагами головок «REA» (RAY) є:

високоточна коробка передач з меншим шумом і довшим терміном служби;

кожна частина має серійний номер, що сприяє контролю якості продукції;

низька швидкість деформації бурильної труби з тривалим терміном служби;

дробеструйна обробка деталей не тільки забезпечує якісну обробку поверхні, але й запобігає утворенню іржі та продовжує термін служби;

якісна упаковка для надійного захисту машини, коли вона надходить на склад клієнта, що зменшує кількість після продажних проблем.

Всі планетарні приводи в лінійці сконструйовані та створені для високої довговічності, забезпечуючи універсальність і якість продукції «REA».

Привід шнека розроблений для роботи з усіма марками та моделями основної машини та доповнений рядом насадок для будь-яких потреб. Завдяки універсальності приводів здійснюється їх легке перемикання між навісними пристроями машини.

В гідроприводі обертання шнеку встановлений двоходовий клапан шнекового моменту, який є додатковою опцією цієї серії бурових приводів і дозволяє автоматично при підвищенні тиску до максимального допустимого значення розвантажити насос шляхом перепуску робочої рідини з лінії нагнітання насосу на злив в гідробак.

На рис. 2 приведені складові частини бурильного приводу REA20000.

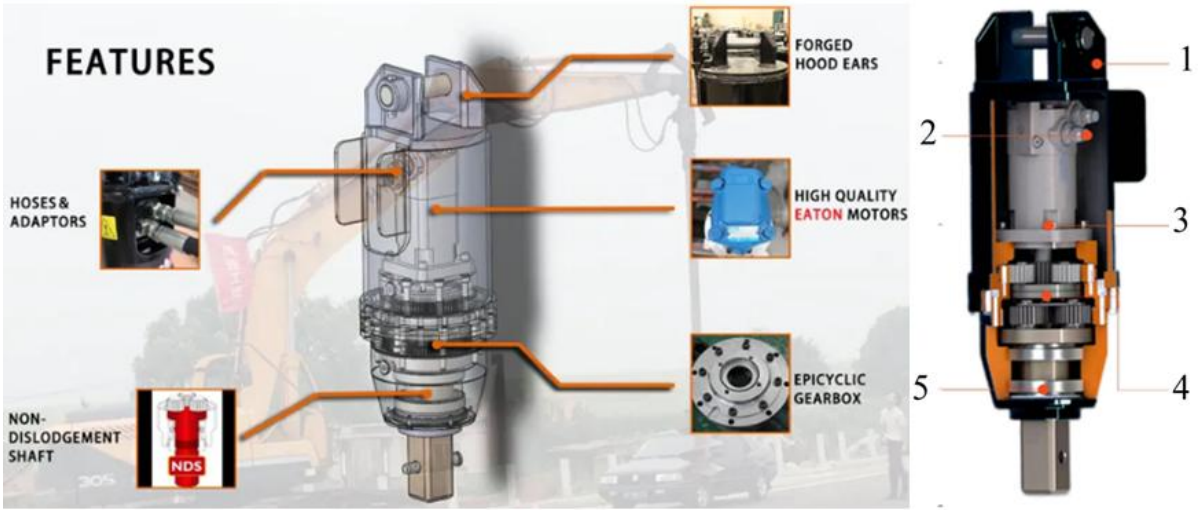


Рис. 2. Деталі бурильного привода REA20000: Hoses adaptor (перехідник для шлангів); Non-dislogment Shaft (вал без деформацій); Forged hood ears (кованe кріплення приводу); Hiqh quality Eaton motors (високоякісний гідромотор фірми Eaton); Epicyclic gearbox (епіциклічний редуктор); 1 – кріплення до стріли машини; 2 – перехідник для рукавів високого тиску; 3 – героторний гідромотор; 4 – планетарний багатоступеневий редуктор; 5 – вихідна частина редуктора для кріплення бурового шнеку

В табл. 1 приведені основні технічні характеристики бурильних приводів «REA» обраних 5 з 20 типорозмірів за крутним моментом: від мінімального REA2000 в 1871 Н.м до максимального REA100000 з крутним моментом 103509 Н.м. Діаметри вихідних валів знаходяться в діапазоні від 65 мм до 150 мм, діаметри з'єднувальних трубопроводів від 1/2" до 1 1/2" залежно від типорозміру бурильної головки. Мінімальні діаметри шнеків: 100 мм для моделей REA2000-REA4500; 150 мм для моделей REA5000-REA25000; 300 мм для моделей REA35000-REA100000).

Таблиця 1.

Технічна характеристика декількох шнекових приводів REA

Параметр, розмірність	Модель шнекового приводу REA:						
	2000	10000	20000	35000	50000	65000	100000
БМ, т	1-2,5	10-13	13-20	20-45	20-45	20-50	20-50
M, Н.м	1871	10778	19560	35265	47389	62197	103509
p, МПа	21	24	24	31	32	35	35
q, л/хв	23-53	70-136	80-170	80-170	100-280	100-280	100-280
n, $хв^{-1}$	40-92	26-45	16-33	9-24	11-30	9-25	5-13
m, кг	54	167	270	440	470	490	1350
H, мм	595	930	1150	1410	1410	1450	2010
D, мм	200	290	345	406	406	406	675
$H_{шн}$, мм	1200	1750	1750	2300	2300	2300	2300
$D_{шн}$, мм	400	900	1200	1500	1800	1800	1800

Примітки: БМ – маса базової машини для встановлення приводної головки REA; M – максимальний крутний момент; n – діапазон частоти обертання шнека; p – максимальний тиск в гідроприводі; q – діапазон витрат робочої рідини; m – маса приводного блоку; H і D – довжина і діаметр приводної головки; $H_{шн}$ – довжина шнеку; вказані максимальні діаметри шнеків $D_{шн}$.

Для вирішення завдання щодо створення безредукторного привода шляхом обрання високомоментного гідромотора замість привода з героторним гідромотором і редуктором виконаємо відповідний інформаційний пошук.

Високомоментні гідромотори повинні задовольняти вимогам щодо крутного моменту, частоти обертання, а також вихідної потужності. В каталозі REA такі параметри не приведені, тому виконаємо розрахунок потужності приводів за формулою:

$$P = \frac{M_{шн} \cdot n_{шн}}{9550}, \text{ кВт.} \quad (1)$$

де $M_{шн}$ – крутний момент, що розвиває шнек, Н.м,

$n_{шн}$ – частота обертання шнека, $хв^{-1}$.

Результати розрахунків потужності приводів «REA» приведені на рис. 3, де показано, що значення потужності знаходиться в діапазоні від 18 кВт до 163 кВт залежно від типорозміру.

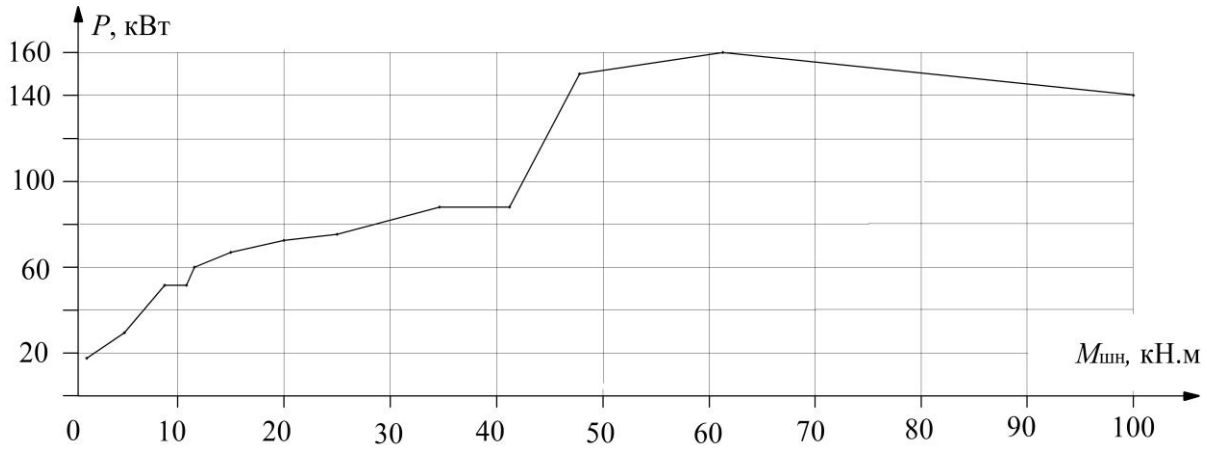


Рис. 3. Потужність приводів REA від значення крутного моменту

Для аналізу можливості створення альтернативного безредукторного за конструкцією гідроприводного бурильного обладнання шляхом застосування високомоментного гідромотора в якості аналога обираємо привод REA10000 з максимальними значеннями крутного моменту в 103509 Н.м і частотою обертання від 5 $хв^{-1}$ до 13 $хв^{-1}$. Виконуємо такий аналіз на основі інформаційних матеріалів виробників високомоментних радіальнопоршневих гідромоторів одноциклової (ексцентрикової) і багатоциклової дії. В сучасній номенклатурі виробників знайдені такі високомоментні радіальнопоршневі гідромотори, що мають необхідні характеристики за крутним моментом та частотою обертання:

одноциклової дії моделі MRTE і SMA;

багатоциклової дії MI 250 і CBP CB MB.

В табл. 2 приведені порівняльні характеристики приводу REA100000 і високомоментних гідромоторів. За крутним моментом всі високомоментні гідромотори влаштовують щодо досягнення значення в 103509 Н.м при тиску менше ніж максимальний. Але щодо показників маси, то тільки гідромотори багатоциклової дії MI 250 і CB400-360

мають перевагу на приводом REA. Конструкції гідромоторів одноциклової дії суттєво поступаються приводу REA.

Для оцінки технічного рівня за масою розглядам відношення маси привода або гідромотора до крутного моменту:

$$k_M = m / M_{\text{шн}}, \text{ кг/кН.м}, \qquad (2)$$

де m – маса шнекового привода або гідромотора, кг,

$M_{\text{шн}}$ – крутний момент на виході шнека аба гідромотора, кН.м.

Суттєву перевагу, майже в 1,3…1,5 разів, за показником k_M мають гідромотори MI250-7(8) і CB400-360.

Для розрахунку необхідної витрати робочої рідини для гідромотора використовуємо таку формулу:

$$Q_{\text{м}} = \frac{10^{-3} \cdot V_{\text{м}} \cdot n_{\text{шн}}}{\eta_{\text{ом}}}, \text{ л/хв}, \qquad (3)$$

де $V_{\text{м}}$ – робочий об'єм гідромотора, см^3;

$\eta_{\text{ом}}$ – об'ємний ККД гідромотора.

Підвищений перепад тисків в гідромоторі MI250-7 значенням 37,2 МПа дає можливість мінімізувати робочий об'єм насоса в порівнянні з гідромотором MI250-8 і знизити витрату до 228 л/хв, що майже в 1,2 рази менше в порівнянні з приводом REA. Зменшення робочого об'єму насоса дає такі переваги як можливість зменшення маси і ціни насоса, втрат потужності в режимі холостого ходу, а також діаметрів трубопроводів.

Таблиця 2.

Технічні характеристики високомоментних гідромоторів з максимальним крутним моментом 103509 Н.м в порівнянні з приводом REA100000 (гідромотора з редуктором ГМР)

Модель	$V_{\text{м}}$, см^3/ Δp, МПа	$p^{\text{тх}}_{\text{м.макс}}$, **МПа**	q, **л/хв**	**D x L, мм**	m, **кг**	k_M, кг/кН.м
REA 100000	**ГМР/35**	**35**	**100…280**	**675x1450**	**1350**	**13,0**
MI250-7	**17500/37,2**	**45**	**88…228**	**631x959**	**920**	**8,9**
MI250-8	**20000/32,6**	**45**	**100…260**	**631x959**	**920**	**8,9**
CBP400-320	**20100/32,4**	**35**	**101…261**	**940x959**	**1890**	**18,3**
CB400-360	**20100/32,4**	**35**	**101…261**	**782x619**	**1060**	**10,2**
MB400	**25145/25,9**	**35**	**126…327**	**1044x784**	**1625**	**15,7**
MRTE23000	**23000/28,3**	**35**	**115…299**	**1014 x1215**	**3100**	**29,9**
SMA-L1C1	**16400/39,7**	**49**	**82…213**	**1140x896**	**2443**	**23,6**

Примітки: 1. Над рисою вказаний робочий об'єм гідромотора за каталогом, під рисою вказаний перепад тисків, при якому розвивається крутний момент в 103509 Н.м, що відповідає характеристиці привода REA 100000;

2. $p^{\text{тх}}_{\text{м.макс}}$ – максимальний тиск згідно технічній характеристиці гідромотора за каталогом; 3. q – теоретична витрата гідромотора для створення частоти обертання в діапазоні від 5 хв$^{-1}$ до 13 хв$^{-1}$, що відповідає частоті обертання привода REA 100000; 4. D x L – діаметр та довжина привода (гідромотора); 5. m – маса привода (гідромотора).

Розглянемо технічні характеристики високомоментних гідромоторів і особливості їх застосування в бурошнекових приводах.

Гідромотори багатоциклової дії серії MS фірми «Poclain Hydraulics» мають робочі об'єми від 172 см^3 до 15000 см^3 і створюють крутний момент від 1231 Н.м до 76320 Н.м [10]. Для гідромоторів з робочим об'ємом до 10000 см^3 максимальний тиск досягає 45 МПа, для типорозміру в 15000 см^3 максимальний тиск обмежений значенням 32 МПа. Маса гідромоторів від 21 кг до 460 кг. Слід відзначити позитивну конструктивну особливість гідромоторів щодо можливості зменшення робочого об'єму у два рази. Таке конструктивне рішення дає можливість працювати при зменшених зовнішніх навантаженнях з підвищеними частотами обертаннях і без нарощування настановної потужності насоса і приводного двигуна. Такий підхід сприяє енергозбереженню і зменшенню витрат на бурильне обладнання. Гідромотори серії MS охоплюють всі можливі типорозміри бурошнекових приводів крім REA100000 з максимальним крутним моментом. Для цього привода можна скористатися гідромоторами серії MI250, які в останні роки створила фірма «Poclain Hydraulics». Гідромотори з робочими об'ємами від 17500 см^3 до 30000 см^3 в одній базі мають масу 920 кг (рис. 4) [10]. Гідромотор моделі MI250 складається з валу 1, двох кулачків-копирів 2 та 3, поршневих груп 4 і 5 (поршень-ролик), блоку 6 з торцевими гідророзподільниками 7 і 8, підшипників 9 та 10, фланця 11 та ущільнення 12. Особливість конструкції полягає в тому, що розподільний вузол 6 розміщений компактно в одному блоці всередині гідромотора, а поршневі дворядні групи 4 і 5 по обидва боки від розподільного вузла. Найкращий показник моменту досягає K_M = 5,51кг/кН.м, а потужності K_P = 1,84 кг/кВт, однаковий для всіх.

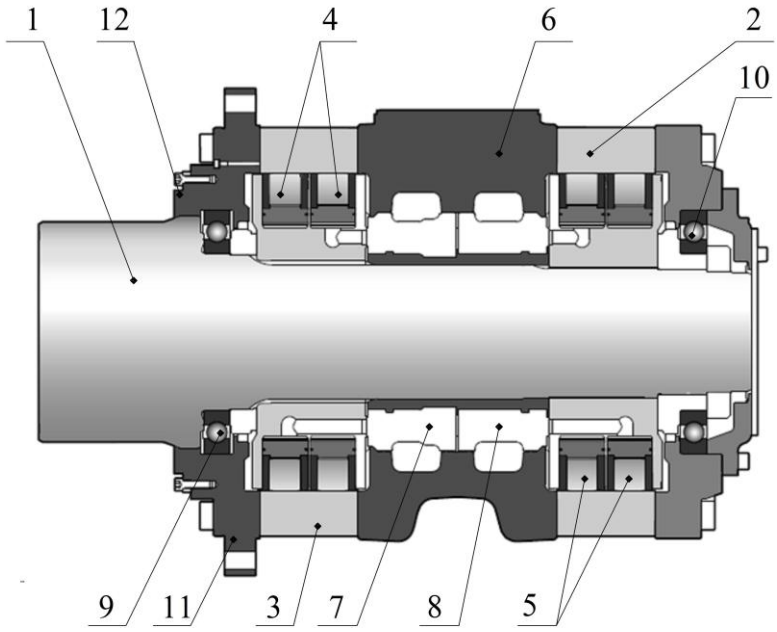


Рис. 4. Радіальнопоршневий багатоцикловий гідромотор серії MI 250 фірми «Poclain Hydraulics»

Гідромотори «Compact CA-Hagglunds» компанії «Rexroth Bosch Group» включають 5 серій (CA50, CA70, CA100, CA140 і CA210) з робочим об'ємом від 1256 см^3 до 13200 см^3 (21 типорозмір) на максимальний тиск 35 МПа і розвивають крутний момент від 7 кНм до 73 кНм [11]. Максимальна частота обертання гідромоторів від 400 хв$^{-1}$ до 115 хв$^{-1}$. Маса гідромоторів від 175 кг до 395 кг. Таким чином, гідромотори моделі Compact CA можуть бути застосовані в якості альтернативних безредукторних гідроприводів з обмеженням щодо максимального крутного моменту відносно моделі REA100000. Є конструктивне виконання гідромоторів зі шліцьовим зовнішнім та порожнистим валами. Загальний ККД гідромоторів досягає 96%, гідромеханічний 97%, що відповідає повному 93%. Для забезпечення надійної роботи гідромоторів рекомендується введення прокачування РР через корпус у межах 20 л/хв: для серій CA50/70 при потужності понад 60 кВт, для серій CA100/140/210 при 120 кВт. Гідромотори мають регульоване по робочому об'єму виконання у співвідношенні 1:2. Основними областями застосування гідромоторів є приводи обертання стаціонарних та суднових машин.

Радіальнопоршневий гідромотор моделі CA (рис. 5) включає копір 1, яким переміщаються ролики 2, що спираються на поршні 3, розміщені в радіальних розточках блоку циліндрів 5.

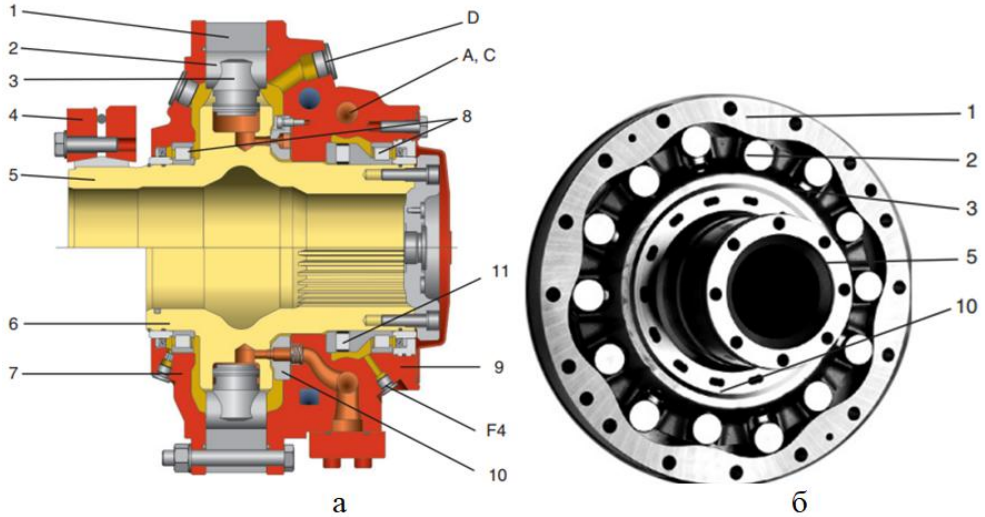


Рис. 5. Радіальнопоршневий гідромотор моделі «Compact CA-Hagglunds» компанії «Rexroth Bosch Group»: а – поперечний розріз; б – основні деталі при знятій задній кришці

Муфта 4 служить для передачі крутного моменту і частоти обертання від блоку циліндрів 5 з внутрішнім шліцевим валом 6 робочого органу. Вал 6 встановлений в корпусі 7 за допомогою роликових підшипників 8. На торці з'єднувального блоку 9 встановлений розподільний диск 10. Осьове зусилля на блок циліндрів 5 з боку розподільного диска 10 сприймається радіальним упорним роликовим підшипником 11. У гідромоторі є два отвори А і один отвір С для повідомлення з насосом і (або) гідробаком, три отвори D для відведення дренажних витоків і отвір F4 для прокачування корпусу гі-

дромотора оливою з метою охолодження вузлів тертя кочення - підшипників 8 і 11, роликів 2 та поршнів 3 в отворах блоку циліндрів 5, розподільного вузла 10. Представлений на рисунку гідромотор має 14 поршнів і копір з 8 кулачками, тобто за один оборот валу один поршень здійснює 8 робочих ходів нагнітання оливи. Найкращий показник моменту досягає K_M = 7,15 кг/кН.м, а потужності K_P = 0,27 кг/кВт для гідромотора СА 210.

Гідромотори «COMPACT CBP-Hagglunds» компанії «Rexroth Bosch Group» [12] складаються з чотирьох базових серій 140, 280, 400, 560 і 850 на максимальний тиск 35 МПа і включають 24 робочих об'єма від 5024 см^3 до 52800 см^3 і крутний момент від 28 кНм до 294 кНм. Частота обертання гідромоторів від 115 хв$^{-1}$ до 400 хв$^{-1}$. Гідромотор серії CBP (рис. 6) включає копір 1, ролики 2, встановлені в поршнях 3, розміщених у радіальних розточках блоку циліндрів 4. Блок циліндрів 4 містить шліцевий отвір в осьовому розточуванні і встановлений в корпусах 7 (з'єднувальних блоках) за допомогою роликових підшипників 6. Фланець 5 гідромотора служить для кріплення до робочого органу гідрофікованої машини. Гідромотор має торцевий розподільний вузол, що складається з двох оппозитних дисків 8, щодо яких обертаються торцеві площини блоку циліндрів 4 з отворами для сполучення з поршням гідромотора. Для повідомлення з магістралями гідросистеми (насосом і гідробаком) служать отвори A і C, для зливу витоків в гідробак служать дренажні отвори D. Осьові навантаження з боку розподільних дисків на торці блоку циліндрів сприймаються радіальними упорними роликовими підшипниками, розміщеними в передньому і задньому сполучних блоках 7. Найкращий показник моменту досягає K_M = 6,24 кг/кН.м для гідромотора CBP 140.

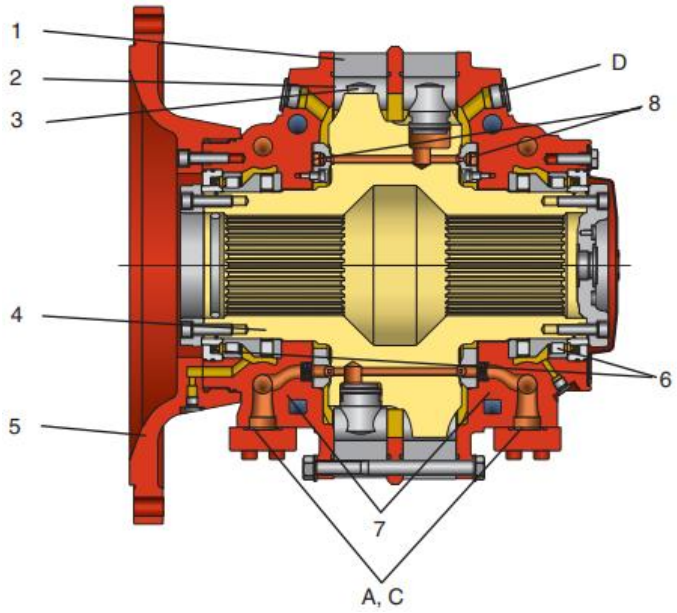


Рис. 6. Радіальнопоршневий гідромотор багатоциклової дії серії «COMPACT CBP» фірми «Hagglunds Drives AB»

Гідромотори серії «Compact CB» фірми «Hagglunds Drives AB» включають 29 типорозмірів з робочим об'ємом від 15100 см^3 до 70400 см^3 на максимальний тиск 25...35 МПа, крутним моментом від 79 кН.м до 370 кН.м, частотою обертання 27 хв$^{-1}$…125 хв$^{-1}$ [13]. Для всіх гідромоторів зазначений гідромеханічний ККД в 98%. Маса гідромоторів від 705 кг до 1770 кг (для виконання з фланцем та отвором для встановлення шліцьового валу). Для номінальної частоти обертання встановлено мінімальне значення тиску на зливі 1,2 МПа. Гідромотори серії «Compact CB» мають постійний робочий об'єм.

Гідромотор (рис. 7) містить профільний копір 1, по якому переміщуються ролики 2, встановлені в поршнях 3 і розміщені в радіальних розточках блоку циліндрів 6. Передача крутного моменту від блоку циліндрів гідромотора на робочий орган гідрофікованої машини може здійснюватися за допомогою муфти 4 або порожнистого шлицьового валу 5. У корпусі 7 гідромотора встановлені роликові радіальні підшипники 8 і упорні 11 для сприйняттів осьового зусилля з боку торцевого розподільного диска 10, встановленого в задній кришці 9. У задній кришці 9 є також отвори A і C для повідомлення РР з магістралями високого (насоса) і низького (злив у бак) тиску та D для відведення витоків з корпусу гідромотора в бак.

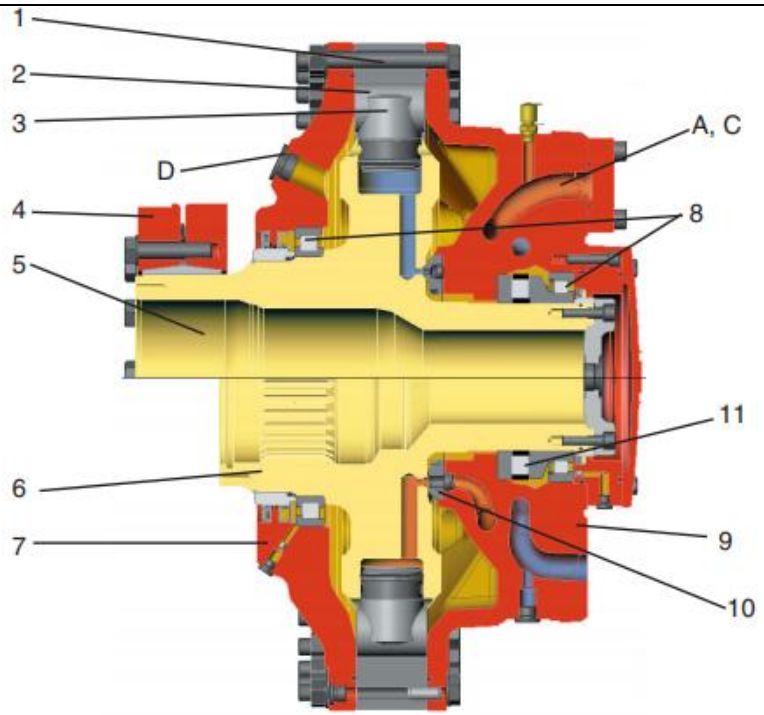
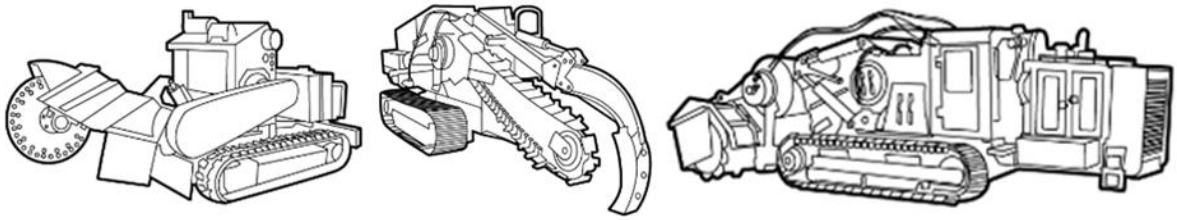


Рис. 7. Радіальнопоршневий гідромотор багато циклової дії моделі «Compact CB» фірми «Hagglunds Drives AB»

Для експлуатації гідромоторів рекомендується робоча рідина, що допускає не менше 11 ступенів навантаження за «редукторним» тестом FZG DIN 51354, температура рідини від «мінус» 35°С до 70°С, клас чистоти 18/16/13 згідно ISO 4406:1999, діапазон коефіцієнта кінематичної в'язкості в межах від 20 сСт (мм^2/с) до 10000 сСт. Рекомендований індекс в'язкості ІВ від 100 до 150. Допускається експлуатація гідромоторів на вогнестійких робочих рідинах. Гідромотори мають конструктивні виконання у 2 або 4 отвори для сполучення з магістралями насоса. Збільшення кількості отворів дозволяє знизити гідравлічні втрати та підвищити максимальні ККД гідромотора на 1%. Об'ємні втрати в гідромоторах (внутрішні та зовнішні витоки) становлять від 7 л/хв до 23 л/хв (залежно від робочого об'єму) при тиску 35 МПа і в'язкості рідини в 40 сСт.

Для експлуатації в замкненому ланцюгу циркуляції робочої рідини рекомендується промивання гідросистеми шляхом скидання 15% частини витрати в гідробак. Крім того, фірма дає вказівку, що максимальна потужність гідромотора без прокачування рідини через корпус не повинна перевищувати 120 кВт для базової моделі СВ в 280 кВт і 170 кВт для базових моделей СВ 400…1120. Для роботи на низьких частотах обертання (менше 3 хв$^{-1}$) рекомендується використання робоча рідина підвищеної в'язкості та конструкції поршня типу coated piston and cam rollers.

Слід також звернути увагу на радіальнопоршневі гідромотори одноциклової дії, які широко застосовують в будівельно-дорожніх машинах. Так фірма «Rotary Power» (Англія) [14] має досвід застосування гідромоторів моделі SMA в подрібнювачах пнів, траншеєкопачах та для вирівнювання місцевості (рис. 8). Типорозмірний ряд гідромоторів складає 15 моделей з робочим об'ємом від 2000 см^3 до 16400 см^3 на максимальний тиск 49 МПа, що дозволяє створити крутний момент в 100000Н.м і створити безредукторний бурильний привід як аналог моделі REA100000. Але такий привід суттєво поступається за масою приводу REA100000.



а *б* *в*

Рис. 8. Машини, в яких застосовують гідромотори SMA: а – подрібнювач пнів; б – траншеєкопач; б - вирівнювач місцевості

На рис. 9 приведена конструкція гідромотора SMA, на якому позначені такі основні деталі: piston pad (опора поршня); piston (поршень); distributor end cover (кришка розподільника; distributor sealing ring (кільцеве ущільнення розподільника); distributor (розподільник); cylinder block (блок циліндров); crankcase (корпус); piston seal (ущільнення поршня); drive end cover (торцева кришка приводу);

taper roller bearing (конічний роликовий підшипник); crankshaft (ексцентриковий вал); seal cover (корпус ущільнення); coupling (муфта).

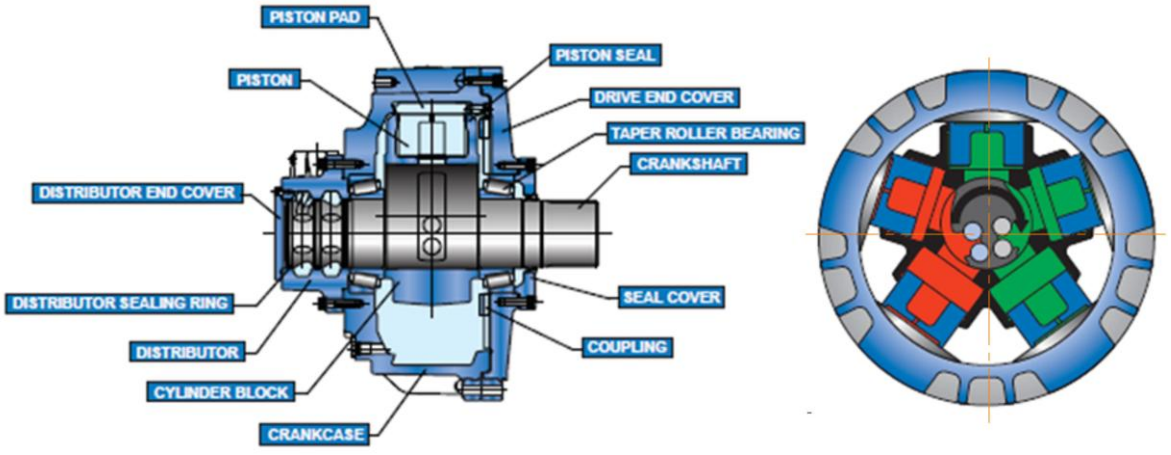


Рис. 9. Радіальнопоршневий гідромотор ексцентрикової дії моделі SMA

Широкій досвід застосування в бурильних приводах мають гідромотори одноциклової дії моделі MR (рис. 10) фірми «Calzoni» (Італія), які рекламуються також фірмою «Parker» (США) [15].

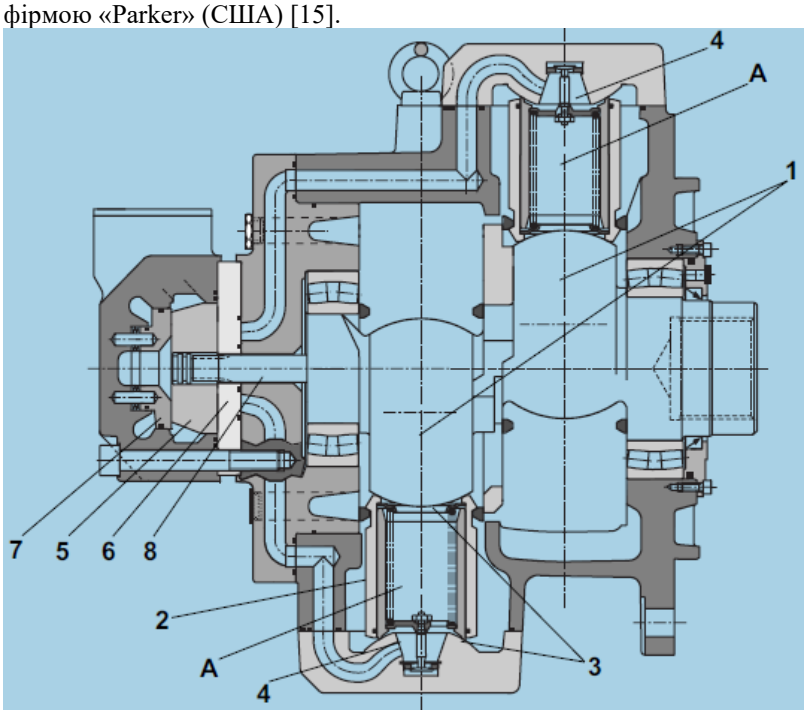


Рис. 10. Радіальнопоршневий гідромотор одноциклової (ексцентрикової) дії моделі «MR-Calzoni»

Гідромотор має ексцентрикові вали 1, циліндри 2; сферичні поверхні головок циліндрів 3; сферичні опори циліндрів 4 в корпусі; нерухомий розподільний диск 5; обертовий розподільний диск 6; поршень 7 для підтиску диску 6; 8 – муфта. Робоча рідина в поршневій порожнині позначена літерою А. Принципово за своїми технічними параметрами гідромотори MR задовольнять за значеннями крутних моментів бурильні приводи REA всіх типорозмірів, але також суттєво поступаються їм за масою.

При створенні альтернативних гідроприводів з високомоментними гідромоторами треба також відмітити, що наприклад, при використанні гідромотора MI250 фірми «Poclain Hydraulics» крім зменшеної маси (920 кг і 1350 кг в приводі REA100000, відповідно) вдається також зменшити витрату робочої рідини, що дає можливість зменшити робочий об’єм і масу насоса.

Слід визначити, що коректна оцінка застосування високомоментних гідромоторів в якості безредукторних гідроприводів повинна базуватися на результатах функціонально-вартісного аналізу. Крім того, треба оцінювати динамічні характеристики альтернативних приводів. Наприклад, проведені розрахунки динаміки гідропривода з гідромотором «СВм6000-Hagglunds» компанії «Rexroth Bosch Group» [16] вказали на необхідність попереднього моделювання технологічного процесу його роботи з урахуванням моментів інерції обертових

мас, опору зовнішнього навантаження та інтенсивності подачі насоса. Всі ці фактори істотно впливають на функціонування гідропривода з точки зору зниження максимального тиску при пуску і запобігання падінню тиску нижче атмосферного при його зупинці.

Висновки

1. Порівняння технічних характеристик бурошнекових героторних з редукторами приводів та високомоментних радіальнопоршневих гідромоторів показали принципову можливість застосування останніх в якості безредукторної альтернативи.

2. Високомоментні радіальнопоршневі гідромотори багатоциклової дії

MI250-7(8) фірми «Poclain Hydraulics» мають суттєву перевагу за масою і витратою оливи перед героторними редукторними приводами REA100000 фірми «RAY Attachments». Ці переваги дають можливість створити альтернативний гідропривод бурової установки з меншою масою не тільки за рахунок гідромотора, а і насоса зі зменшеним робочим об'ємом.

3. Подальшими етапами в напрямку застосування високомоментних радіальнопоршнвих гідомоторів в мобільних бурошнекових комплексах є проведення експериментальних досліджень і функціонально-вартісного аналізу.

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POLISH JOURNAL OF SCIENCE
№95 (2026)
VOL. 1

ISSN 3353-2389

Polish journal of science:

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